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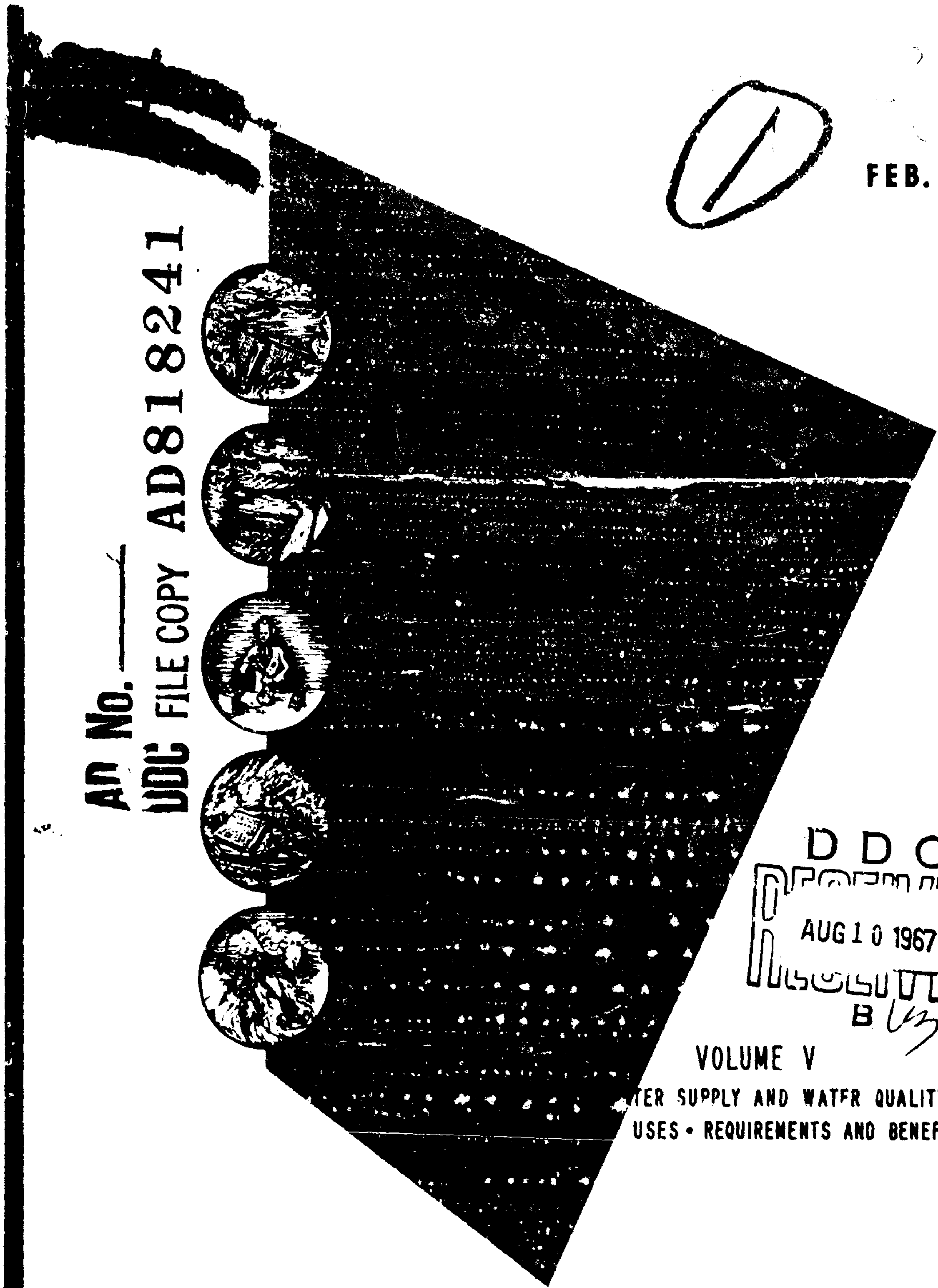

FEB. 1963

VOLUME V

WATER SUPPLY AND WATER QUALITY CONTROL

USES • REQUIREMENTS AND BENEFITS

U.S.ARMY ENGINEER DISTRICT • BALTIMORE

NORTH ATLANTIC DIVISION

6 POTOMAC RIVER BASIN REPORT.

VOLUME V.

APPENDIX E.

WATER SUPPLY AND WATER QUALITY CONTROL

USES, REQUIREMENTS AND BENEFITS.

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REPORT ON THE

POTOMAC RIVER BASIN STUDIES

Public Health Service Activities
in
Corps of Engineers Potomac River Basin Studies

Prepared in Cooperation with the
District Engineer, Baltimore District
Corps of Engineers, U. S. Army

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of State Services
Division of Water Supply and Pollution Control

Region III, Charlottesville, Virginia

and

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

MAY 1962

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SUMMARY

STUDY RESULTS

The Public Health Service has studied the Potomac River Basin water requirements for present and future water supply and quality control. The results are as follows:

1. There is a need for development of water resources to provide storage for water supply and quality control.

2. Adequate treatment of all wastes is required before returning treated effluents to the stream. The Public Health Service study presupposes that waste treatment measures for domestic sewage and industrial wastes of a similar organic nature can achieve at reasonable cost an average reduction of at least 75 percent of the oxygen demanding organic wastes with present methods. It also presupposes that this average will increase to at least 80 percent by 1985 and 85 percent by 2010 for all sub-basins except in the vicinity of the Washington, D. C. Metropolitan Area. In this area the corresponding averages were 80 percent at present, 85 percent by 1985, and 90 percent by 2010. Similarly, with other types of industrial pollutants, process improvements, special treatment, impoundment, or other process changes can substantially reduce the amount of polluting material entering the stream.

3. It is apparent that we do not have a technically practicable and economically feasible means of removing <u>all</u> pollutants. Even after adequate treatment of wastes, natural flows will be insufficient to assimilate the treated residual and attain desired water quality objectives in many stream reaches of the Potomac River Basin.

4. With present knowledge the most practical method of maintaining stream quality after adequate treatment of wastes is increased stream flow from stored water. No known conventional waste treatment method, by itself, exists which will provide stream conditions comparable to that obtained with conventional treatment supplemented by increased stream flow for control of dissolved oxygen, color and persistent waste substances.

5. Benefits will accrue for water supply and quality control if sufficient flows are maintained in stream areas where supplies are limited and where waste treatment residuals exceed the assimilative capacity of the stream at natural flow.

Where quality control by means of stream flow regulation is proposed, only those benefits are credited which would be produced after the waste dischargers have first provided adequate treatment of their wastes.

6. Multiple-purpose reservoirs can be utilized to provide the needed flows for water supply and quality control in a majority of need areas. Any such storage and water releases shall not be provided as a substitute for adequate treatment or other methods of controlling wastes at the source.

   The water requirements (present and projected future) for the Potomac River Basin are summarized in Table 1 with the benefits that could be realized from multiple-purpose reservoirs providing the supplemental flow.

Table 1

STUDY RESULTS

Stream Reach	Water Requirements (cfs) 1960	1985	2010	Flow Increase Required (cfs) 1960	1985	2010	Annual Benefit $1000 1960	1985	2010
North Branch Luke - Cumberland	135	275	435	42	182	342	*411	2,100	4,028
Conococheague Creek Chambersburg, Pennsylvania	44	74	107	32	62	95	*274	536	768
Conococheague Creek Greencastle, Pennsylvania	46	101	209	16	71	179	* 40	290	1,165
West Branch Conococheague Mercersburg, Pennsylvania	26	35	44	10	19	28	133	258	384
Conococheague Creek Below Confluence at West Branch	56	107	220	5	56	169	13	219	1,065
Opequon Creek Winchester, Virginia	31	45	74	31	45	74	407	591	651
Middle River Shenandoah Staunton - Verona	47	83	112	-	34	63	-	85	186
South River Shenandoah Waynesboro, Virginia	149	215	270	78	131	170	263	365	446
South Fork Shenandoah Elkton, Virginia	259	356	440	75	182	272	368	846	1,251
South Fork Shenandoah Below Mouth of Hawksbill Creek	251	342	415	21	112	190	59	357	974
South Fork Shenandoah Front Royal, Virginia	248	336	419	-	99	190	-	319	979
Shenandoah River Riverton, Virginia	244	339	418	-	33	124	* -	103	588
North Fork Shenandoah Broadway, Timberville, New Market, Virginia	105	146	187	82	123	164	*523	798	1,037
North Fork Shenandoah Mt. Jackson, Edinburgh, Virginia	70	102	130	39	77	110	110	281	473
North Fork Shenandoah Woodstock, Strasburg, Virginia	34	56	71	-	11	32	-	30	122
Shenandoah River Millville, Charles Town, West Virginia	244	344	430	-	-	108	-	-	329
Monocacy River Frederick, Maryland	90	156	229	38	108	186	91	419	1,228
Potomac River Dickerson, Maryland	400	603	785	-	-	-	* -	527	1,339
Potomac River Great Falls and Downstream	3,392	4,549	5,339	2,292	3,609	4,519	6,303	11,188	14,913

* Includes Cooling Benefits

INTRODUCTION

Under the Federal Water Pollution Control Act, the Public Health Service has responsibility for the development of comprehensive programs for water pollution control. The development of such programs includes consideration of improvements necessary to conserve water quality for all legitimate water uses. The law also requires that the need for and value of storage in any Federal reservoir which will include storage for regulation of stream flow for water quality control purposes shall be determined by the Federal agencies with the advice of the Secretary, Department of Health, Education, and Welfare.

A memorandum of agreement between the Department of the Army and the Department of Health, Education, and Welfare sets forth assistance to be provided by the Public Health Service to the Corps of Engineers in implementing the Water Supply Act of 1958. This act provides for inclusion of storage for municipal and industrial water supply in Federal reservoirs. The Public Health Service, over the years, has cooperated with the Corps of Engineers in making water quality studies and evaluating water supply and flow augmentation aspects of reservoir storage.

As a part of the project for development of a comprehensive water resources plan for the entire Potomac River Basin, the Corps of Engineers in 1956 requested the Public Health Service to study aspects of water supply and water quality in the Basin. The objective of the study was to provide information essential to the formulation of the plan.

The Public Health Service began active participation in the Corps of Engineers study in the fall of 1956. The studies of the Service have, in conjunction with the Corps of Engineers and other agencies, been concerned with all aspects of water supply and water quality control. One of the first steps taken was an inventory of existing water supplies and their use, sources of waste, stream flows and existing populations and industries. This was a continuing process throughout the study and data obtained subesquent to the original tabulations were incorporated into the report as needed.

Special field studies were made to supplement existing information relative to water quality, stream characteristics, suitability of the water for various uses, with emphasis on municipal water supply, and ability of streams and the tidal estuary to receive wastes commensurate with maintenance of water quality objectives. This program of studies was designed to cover all significant streams in the Basin. To accomplish this end, the Basin was divided into several areas and field work planned for each year as available funds and personnel would permit. Thus, the North Branch

Potomac drainage area was investigated in 1956, the Potomac River main stem and most tributaries in 1958, the tidal estuary in 1959, and the Shenandoah Basin in 1960.

In addition to the actual stream sampling and laboratory analyses, these investigations included meetings and discussions with officials of local communities and industries to obtain their estimates of present and future water supply requirements. Existing water quality data were also obtained from the Interstate Commission on the Potomac River Basin, industries and the State agencies. The object of this work was to gather data from which estimates could be made for future municipal and industrial water supply needs and the need for reservoir storage for the purpose of maintaining desired water quality in the stream.

Establishment of water quality objectives was essential to the formulation of these estimates. The objectives adopted must be complete enough to cover the quality requirements for fish and wildlife, recreational and other "in stream" uses, as well as the dominant need of municipal water supply. Since the Interstate Commission on the Potomac River Basin had adopted recommended water quality criteria within the Basin which met the above requirement, it was decided to use these criteria as the basic water quality objective.

Domestic water supply requirements are assigned the highest priority in the determination of future water needs. The essential human need for the best possible drinking water must be satisfied before consideration can be given to the use of stream waters for other purposes, such as industrial process or cooling needs, or for dilution of effluents from sewage and industrial water treatment plants.

The projection of population and industrial growth is basic to the preparation of forecasts of future water supply needs. This information for major subdivisions within the Basin was supplied by the Department of Commerce, Office of Business Economics. These data, coupled with information obtained from individual communities and industries, was utilized by the Public Health Service to develop estimates of future water uses.

Current per capita water use was determined for all significant water supplies, future per capita increases were estimated in accordance with established national and regional trends. For example, current water supply use in one area was found to be 85 gallons per capita per day in 1960. This was estimated to gradually increase to about 120 gallons per day in 1985, and to 150 gallons per day in the year 2010. Similar figures vary considerably for the many Basin subdivisions used in the study. The per capita figures developed, combined with population forecasts, resulted in the estimate of future municipal water supply requirements.

Industrial water needs for both cooling and process uses were based on the Office of Business Economics projections of employment and income for existing types of industries within the Basin.

The amount of water needed over and above natural stream flow for maintenance of water quality was determined largely upon information developed by the stream sampling program. Existing water quality and effects of municipal and industrial waste discharges on the Basin's streams were determined by means of sample collection and laboratory analyses. These data, combined with projections of population and industrial growth, formed the basis for estimates of future waste loads and water quality.

In preparing these estimates it was necessary to make assumptions relative to the residual waste loads that would be discharged to the streams following waste treatment. The plan of development presupposes the attainment of waste control at a level of 80 and 85 percent in the basin in the years 1985 and 2010, respectively, except in the metropolitan area of Washington where levels of 85 and 90 percent are required. These degrees of treatment were considered the maximum attainable within existing or foreseeable practical and economic limits. It should be noted that these are average levels obtainable at all times and are applied to all wastes generated in the basin. A complete collection of all waste is not possible and treatment plants cannot work at maximum efficiency at all times. The design efficiency of the treatment plants needed to reach the assumed goal must be considerably higher than that goal. It was further recognized that conventional treatment processes, as we now know them, cannot remove all contaminants important in maintaining suitable water quality. Such things as detergents in sewage and color resulting from paper manufacture fall into this category. Similarly, nutrients of importance to the growth of aquatic organisms are not removed by present day treatment processes.

With these considerations, it was found that at many points and on a majority of the streams, future water quality objectives could not be met under natural flow conditions. Calculations of additional water needed at each point were then made.

In the upstream areas it was found that there is generally an adequate volume of water for municipal use, even though substantial future development can be expected to occur. Protection of the quality of water will, however, be a problem. Maintenance of water quality without the provision of additional water over and above natural low flows will be difficult, if not impossible, in some areas. The North Branch drainage area, parts of the Shenandoah Basin, the Monocacy sub-basin and the Conococheague-Antietam Creeks are most prominent in this respect.

The most complex problems and those most difficult to solve exist in the Washington Metropolitan Area where by the year 2010 about 70 percent of the Basin population will reside. This is due largely to the fact that the Potomac River loses its identity as a typical flowing stream and becomes a tidal estuary.

The waste assimilation capacity of the estuary is controlled by four major factors: (1) tidal action, (2) waste load discharged, (3) sunlight, and (4) river discharge. The dissolved oxygen concentration results from the interplay of these factors and is the parameter by which the waste assimilation capacity is measured. Other factors contribute to the observed dissolved oxygen values, but their effects are minimal compared to the major factors.

In analyzing the collected data, the net effect of all the major factors influencing the assimilative capacity was determined. The separate effects contributed by tidal action, sunlight, waste loads, and river discharge were also calculated. A relatively new method of data processing called spectral analysis was utilized to obtain the answers. Computers were used to carry out the computation, and the programming for the operation was developed at New York University. The results of the study indicate that the maintenance of recommended water quality criteria of the Interstate Commission on the Potomac River Basin can be expected if a minimum flow of about 3,750 cfs can be provided to the estuary during critical periods.

Another of the problems encountered in carrying out this long-term study was that of keeping up with Basin progress. Since the study began in 1956, 58 waste treatment projects have been initiated with assistance of Federal grants under the Public Health Service Construction Grants Program. The District of Columbia and Fairfax County have added secondary treatment. Improvements have been made at Alexandria and Arlington. The Potomac Interceptor, planned to convey wastes from Dulles International Airport and other sources in Virginia and Maryland to the District of Columbia, is now under construction. A large combination plant for treating both domestic sewage and industrial wastes has been built at Luke, Maryland. In all, the expenditure for waste collection and treatment facilities constructed or now under construction within the basin can be conservatively estimated at over $60 million.

The situation in the Potomac River Basin is dynamic and ever changing. The Public Health Service studies have established flows needed in the Basin and to the estuary that would be required to maintain desired water quality. However, this is not the end point. Expansion of population and improvements in waste treatment will cause water quality to vary from day to day and year to year. A real need still exists for increased knowledge of estuarine waters. The complex nature of the Potomac estuary will require that

continuous monitoring be carried out in the future in order to evaluate the changing patterns in water quality.

A detailed account of the studies carried out by the Public Health Service on the Potomac River Basin can be reviewed in the eight parts following this Summary, which are:

This Summary points out the highlights of the eight parts and reviews the requirements and benefits that may accrue from major reservoirs considered for flow regulation.

DESCRIPTION OF THE BASIN

From its headwaters on the eastern slopes of the Appalachian Mountains, the Potomac flows in a general southeasterly direction some 400 miles to Chesapeake Bay. The main stem is formed approximately 20 miles below Cumberland, Maryland, at the confluence of the North and South Branches of the Potomac and flows southeast to the Fall Line at Great Falls, Virginia. About ten miles below the Falls at Chain bridge, the lower river or tidal section is formed.

The portion of the Potomac River above the Fall Line is about 266 miles long and follows a course through the mountainous terrain of the Alleghenies, across the fertile Shenandoah Valley, through the Blue Ridge Mountains, and across the rolling hills of the Piedmont Plateau to the Fall Line and the Coastal Plain. It drains an area of about 11,500 square miles in Maryland, Pennsylvania, West Virginia, and Virginia. It is a comparatively narrow fast-flowing stream flanked by steep banks and mountains, and has many natural obstructions and rapids.

The Potomac tributaries possess essentially the same features as the main stem above the Fall Line. The Shenandoah River is the largest tributary stream of the Potomac River and is located entirely within the State of Virginia with the exception of 72 square miles (2.3 percent of total drainage area) near the mouth in West Virginia. It occupies the northwestern corner of Virginia and most of its westerly edge forms a portion of the State line between Virginia and West Virginia. It flows along the western base of the Blue Ridge Mountains and enters the Potomac River near Harpers Ferry, West Virginia, a distance of 171 river miles above the mouth of the Potomac River at Chesapeake Bay, and 60 miles upstream from Washington, D. C. Maximum discharges of more than 200,000 cubic feet per second and minimum discharges of less than 200 cubic feet per second have been recorded near the mouth of the Shenandoah.

South Branch Potomac Basin is the second largest sub-basin of the Potomac with a drainage area of 1,493 square miles. It converges with the North Branch to form the headwaters of the Potomac near Oldtown, Maryland, 285 river miles from the mouth of the Potomac at Chesapeake Bay and 175 river miles above Washington, D. C.

Next largest is the North Branch with a drainage area of 1,328 square miles which constitutes 9.1 percent of the entire Potomac Basin area and 13.3 percent of the drainage area above Washington, D. C. This Basin lies in the extreme western portion of Maryland and in the middle northern section of West Virginia. It drains part of Allegany County and Garrett County in Maryland,

Somerset and Bedford Counties in Pennsylvania, and Grant and Mineral Counties in West Virginia. The North Branch follows a 98 mile northeasterly course converging with the South Branch to form the headwaters of the Potomac.

Other principal tributaries are the Cacapon and Monocacy Rivers, and the Conococheague and Antietam Creek Basins.

The average recorded discharge at Washington, D. C., is 11,340 cubic feet per second. Discharges of 484,000 cubic feet per second and less than 800 cubic feet per second have been recorded. The shape and character of the Basin are such that they favor rapid runoff, with high discharges occurring for short periods of time and low flows existing for sustained periods during drought seasons. The Potomac River and tributaries thus are characterized by flash floods and extremely low flows.

The populations in the Potomac River Basin above Great Falls are located primarily on farms and in numerous communities. The largest community in the region is Hagerstown, Maryland. There are several cities with populations of 10,000 to 20,000. A large proportion of the population is rural. Farming and related industries such as canning, fruit packing, tanning, and dairy products processing are major sources of income to the region.

There are some large industries located throughout the Basin, mainly in the vicinities of Luke, Cumberland, Hagerstown, and Frederick, Maryland; Chambersburg, Mercersburg, Gettysburg, and Waynesboro, Pennsylvania; Harrisonburg, Staunton, Waynesboro, Luray, Front Royal, and Winchester, Virginia; and Martinsburg, West Virginia. These industries include manufacturers of textiles, rubber, paper products, hosiery, small appliances and chemicals in addition to the related agricultural industries already listed.

Parts of the Basin are considered to be among the Nation's most popular recreational areas. There are many historic and scenic attractions, some of which are the Skyline Drive, limestone caverns, the Great Falls of the Potomac, and several Civil War battlefields.

The Upper Potomac River Basin has abundant natural resources including coal, limestone, dolomite, glass sand, clay, hard and soft woods, and granite. These resources offer potentialities for additional large industrial development.

OBJECTIVES

The objectives of the Public Health Service study are: to identify all water use areas; project future water uses in these areas; relate future waste effects to stream sanitation and re-use of waters; discuss waste treatment and rates of stream flow required to meet established objectives for raw water quality; and to compute benefits that would accrue to major reserovirs considered for flow regulation.

It is assumed that the future requirements for water supply given for various areas will be satisfied by use of surface water sources. Although it is known that ground water exists in many areas, insufficient data are available on the dependability of such sources for future use, except in specific instances. Generally, the abundance of ground water appears to exist in areas where more than ample surface water is available to meet demands.

For water use areas located short distances downstream from waste sources, it is recommended that supplies be obtained either directly from major reservoirs or from tributary stream impoundments. Where considered locations for reservoirs are immediately downstream from waste sources, it is recommended that waste effluents be transported to a point below the dam.

It is assumed that within the 50-year period under study municipal waste treatment facilities will provide up to 85 percent BOD reductions of all wastes in the area. The flow requirements given for the years 1960, 1985, and 2010 were based upon 75, 80, and 85 percent BOD removals, respectively, by conventional treatment practices prior to discharge for all sub-basins except in the vicinity of the Washington, D. C. Metropolitan Area. In this area the corresponding averages were 80 percent at present, 85 percent by 1985, and 90 percent by 2010. Treatment plant capacities will necessarily be enlarged at various intervals of time to compensate for waste volume increases, and replacement of units will be made as warranted.

Since it was found throughout the Potomac Basin that industrial waste treatment efficiencies differed greatly depending upon types of waste, it is assumed that future efficiencies will be similar and in some cases greater than presently practiced. For those industries having no treatment, an estimated treatment efficiency is assumed with the expectation that facilities will be installed at a later date.

Stream quality objectives to be achieved by waste treatment and flow regulation are those established by the Interstate Commission on the Potomac River Basin for Class "C" water quality as shown in Table 2. It is assumed that coliform bacteria (MPN) in the stream will be controlled by waste disinfection to monthly averages of no greater than 500-5,000 organisms per 100 milliliters

TABLE 2

Interstate Commission on the Potomac River Basin

Minimum Water Quality Criteria for Streams
in the Potomac River Basin

Approved 8 August 1946

	CLASS A Drinking Water (No treatment except cl.)	CLASS B Bathing, Fish Life	CLASS C Domestic Water Supplies (Before complete treatment) Industrial Process Water	CLASS D General Sanitary Condition - to prevent nuisance
Coliform Bacteria	0 - 50	Mo. av. 50 - 500 Max. not over 1,000	Mo. av. 500 - 5,000	----------
Color, ppm	0 - 10	20 (desirable)	Amt. of color and turbidity allowed which can be removed by standard equipment and practices	----------
Turbidity, ppm	0 - 10	40 (desirable)	----------	----------
pH	6.0 - 8.0	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
5-Day BOD, ppm	----------			
Monthly av., ppm	----------	1.5	2.0	3.0
Max. observation, ppm	----------	3.0	4.0	5.0
Dissolved Oxygen, ppm				
Monthly av., ppm	7.5	6.5	6.5	4.0
Min. observation, ppm	6.5	5.0	5.0	Min. daily ave. 3.0 Absolute min. 2.0
Other Conditions	No toxic substances, oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste - or odor-producing substances.	Same as A	Same as A	No toxic substances, oils, tars, or free acid at any time. No floating solids or debris except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

NOTE: These criteria are to be used only in conjunction with a sanitary survey as a guide in determining the minimum water quality for the various classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.

and that toxic substances--oil, tar, free acid, floating and settleable solids, and taste and odor producing substances--will either be removed by waste treatment or be prevented from entering the streams by other means.

Due to wide differences in stream and waste characteristics found throughout the Potomac Basin, considerable variations in concentrations of BOD associated with dissolved oxygen levels occur. In many instances, for example, depending upon location of certain waste sources in relation to others, the BOD concentrations associated with D.O. levels of 5 parts per million (ppm) may vary from one reach to another or from one stream to another by as much as 5 ppm. Therefore, pollution abatement flow requirement for assimilation of oxygen demanding wastes to meet Interstate Commission established objectives for dissolved oxygen necessarily disregard the objectives for BOD.

To complete the satisfaction of Class "C" water quality objectives, low flow regulation where needed is based on the rate of flow required to maintain average dissolved oxygen levels at 6.5 ppm with monthly minimum levels at 5.0 ppm. It should be understood that the magnitude of stream flow required to maintain these objectives will often accomplish reductions in concentrations of color, taste, odors, and various types of persistent waste chemicals not possible to reduce by any other known treatment means.

STUDY PROCEDURES

PRELIMINARY INVESTIGATIONS

Initial contacts were made with appropriate State and interstate agencies for the purpose of obtaining available information on the water supplies and waste disposal practices in the region being studied. Upon examination of all preliminary data, it was determined that a detailed survey of the Upper Potomac River Basin was required.

Information relative to water uses and waste sources was obtained by direct contact with municipal and industrial representatives concurrently with the water quality sampling programs. As a result of these contacts, a tabulation of data on water uses was prepared and included as Parts I and II.

Part I reviews the proposals made by the Public Health Service to the Corps of Engineers for the collection and evaluation of data, and reports progress relative to the water quality program for the Potomac River Basin.

Part II consists of a systematic tabulation of the data on water supply and waste discharge by municipal and industrial users. Information as to population served, quantity used, use to which the water is put, type of treatment given and quantity of wastes discharged, and receiving stream was listed to be used in the comprehensive analysis.

Any additional information of a preliminary or basic data nature obtained while the stream sampling surveys were conducted was included in Part II New developments subsequent to preparation of Part III are accounted for in the remaining sections of the report.

FIELD INVESTIGATIONS - STREAM SURVEYS

In order to make estimates of future requirements for water supply and quality control, it was necessary to engage in extensive field work to fill gaps in existing data. Current water use was determined and local estimates of future water needs were obtained by means of conferences with officials of local communities and industries. Gaps in water quality data were filled by means of stream sampling programs.

Four intensive stream surveys were conducted during the course of the Potomac River Basin studies.

(1) Investigation of the North Branch Potomac River, September - October 1956. Twenty-three sampling stations on the North Branch and its significant tributaries were selected. A schedule was arranged for sampling all stations at least five times and the more significant locations a minimum of seven times.

(2) Upper Potomac Basin Excluding the North Branch and Shenandoah Basins, September - October 1958. This survey involved forty-two sampling stations in the States of Maryland, Pennsylvania, and West Virginia. The area was divided into six sections in order that each could be sampled and samples returned to the mobile laboratory at Williamsport, Maryland, within a period of six to eight hours. Each section was sampled once a week for a six-week period, with exception of the main stem Potomac River stations which were sampled seven times, and one tributary containing extremely variable waste discharge was sampled thirteen times.

(3) Potomac Estuary Studies, July - August 1959. Field operations were conducted in July and August 1959, with all sampling being carried out by Public Health Service personnel. Two sampling teams, two men each, were available. After preparing the laboratory and conducting exploratory reconnaissance of the river, the collection of samples was initiated on August 6 and completed August 29. Nine stations were finally chosen and continuous twenty-four hour sampling was carried out from Three Sisters Island to Fort Washington. The District of Columbia, Department of Sanitary Engineering, assisted by providing parking facilities and utilities at the Blue Plains Sewage Treatment plant for the mobile laboratory. A sample delivery service was also provided and the Department retained the services of a consulting firm (Resources Research, Inc.) to run laboratory tests beyond the capacity of the Public Health Service mobile trailer laboratory. The Corps of Engineers furnished docking facilities and other assistance, and the United States Air Force made the boat basin at Bolling Field available for emergency docking.

(4) Shenandoah River Basin Survey, May - June 1960. This water sampling program involved 37 sampling stations throughout the Shenandoah Basin in the States of Virginia and West Virginia, and included several additional stations on the Potomac River in Maryland. For sampling purposes, the area was divided into four sections in order that the streams in in each could be sampled conveniently and samples returned to the mobile laboratory located at the Harrisonburg, Virginia, sewage treatment plant within six to eight hours from the time the first samples were collected each day.

CRITERIA FOR DETERMINING PROJECTED REQUIREMENTS FOR WATER SUPPLY AND QUALITY CONTROL

GENERAL

The protection of public health through the provision of a safe water supply for domestic purposes has long been a matter of primary concern to the public health profession and has been a significant contributing factor to the high health standards of the Nation. However, the problem of providing adequate amounts of safe potable water has become increasingly difficult due to the pyramiding water demands of a rapidly expanding population. Furthermore, the resulting increase in waste flows has caused a gradual degradation in the quality of the Nation's waters. While improved methods of treatment and disinfection of both wastes and water have served to maintain the quality within tolerable limits, the progress in pollution abatement and water treatment has not kept pace with this population growth and industrial expansion.

The familiar problems of pollution by bacteria, organic matter, and chemicals of known toxicity and behavior have been further intensified and complicated by problems of mineral enrichment due to water re-use and by new types of contaminants associated with our chemical and atomic age. The effects of these newer contaminants on water treatment processes and on the human consumer are largely unknown. The deficiencies in knowledge and the prospect of even greater quantities and yet more complex pollutional materials reaching our surface waters emphasize the urgency of intelligent water quality management.

It is recognized that water for human consumption holds the highest priority of all water uses. The increased demands on quantity by an increasing variety of uses has also brought about many conflicts which can be solved by intelligent and long-range management prectices. Jnfortunately, practically every water use results in some degradation of quality. As the supply becomes more critical and conflicts in use increase, water quality is assuming increasing importance.

Where alternate sources are available it is desirable to reserve the highest quality water available for domestic use and to satisfy other lower priority demands with waters of lesser quality. In areas of limited supply the ultimate water requirements can be met only by water re-use. Thus, dependence must be placed upon improved and more effective methods of water and waste treatment in order to maintain the highest possible standards of quality for human consumption. However, in such instances every effort should still be made to reserve a sufficient quantity of high quality natural waters for domestic use before they flow on to supply other less critical demands.

It is sound planning to utilize highest quality waters for highest priority uses, and the protection of this quality against irreversible and potentially hazardous degradation must be practiced to the fullest extent possible.

The magnitude of increased water use for all purposes in the United States during the 55-year period (1900-1955) was from 40.2 billion gallons to 262.0 billion gallons per day[1]. The development of American agriculture, industry, rural life, and metropolitan growth has been based primarily upon the availability of an abundant and economical water supply of suitable quality. By 1980, water use in the United States for all major purposes is expected to be 494.1 bgd, or an increase of 230.3 bgd from 1955. Table 3 shows the water uses by categories as estimated for the United States.

Table 3

Water Use in the United States
1900-1980 - U. S. Department of Commerce

Use Category	Billion Gallons Per Day - Average 1900	1955	1980
Irrigation	20.2	116.3	178.0
Rural	2.0	5.4	7.4
Public	3.0	16.3	32.0
Industrial & Miscellaneous	10.0	49.2	115.0
Steam-Electric	5.0	76.6	161.7
All Uses	40.2	263.8	494.1

Studies made on public water supplies indicate that there were about 4,000 supplies serving 30 million people in the year 1900; 17,500 supplies serving an estimated 111 million people in 1955; and by 1980 it is expected that 167 million people will be served by public water supplies in the United States. Such supplies furnish water for domestic, commercial, and industrial purposes within their areas of distribution. The studies on water use incorporated surveys made by the American Water Works Association, the U. S. Public Health Service, and the Water and Sewerage Industry and Utilities Division of the Business and Defense Service Administration, U. S. Department of Commerce. From these sources of information on water uses and Census Bureau figures on populations, it is found that in addition to increased water demands by direct increases in population, the per capita daily average use of water in the United States

1 W. L. Picton, "Water Use in the United States, 1900-1980," Business Service Bulletin, Department of Commerce, (March 1960).

is on the increase. National municipal per capita water use in 1958 was about 150 gallons per day (gpd). In view of past trends, it is reported that the per capita daily average municipal use is expected to average 192 gpd by 1980.[1]

From a study of 58 municipal systems operated by the American Water Works Service Company, Inc., it was revealed that residential sales of water per service for the years 1939-1966 increased fairly uniformly at the rate of about two percent per year.[2] It was also indicated that metered residential sales increased with rising family income. Although data on peak demands were incomplete, available data indicate that maximum daily demands attributed to lawn sprinkling, air conditioning, and refrigeration resulted in demands ranging from 139 to 177 percent of the typical weekday use. These peak demand rates correspond to additional rates of 140-277 gallons per day (gpcd)[2]. The available data showed that the relationship between maximum and average day demands during the period 1939-1956 remained constant.

FUTURE MUNICIPAL AND SANITARY DISTRICT WATER REQUIREMENTS

Because provision of a continuously adequate and potable water supply is basic to public health and the general well-being of the population and economy, planning for future water demands and uses requires the utmost of care and application of a reasonable degree of optimism. This is especially true when planning for requirements 50 years in advance or to the year 2010, as is the objective of this evaluation.

The municipal or public water supply system referred to in this investigation is defined as that facility serving all urban and suburban populations and commercial or small industrial users located within areas of reasonable distribution. A sanitary district water supply system is defined as that facility which serves or may serve unincorporated small town populations, commercial or small industrial users outside of municipal limits, and rural non-farm populations located within areas of reasonable distribution from the facility.

Water requirements for municipal and district uses are given by areas within the drainage basin as governed by centers of population and location with respect to possible reservoir storage sites. Requirements within each area are determined from county population figures projected to the year 2010. Since not all county populations would be served by central water supplies, a division is made into those populations expected to be served by municipal and district supplies, and those expected to have individual supplies. It is assumed that populations in major demand centers will be composed of

[1] W. L. Picton, "Water Use in the United States, 1900-1980," Business Service Bulletin, Department of Commerce, (March 1960).

[2] The Task Committee, American Water Works Association, "Study of Domestic Water Use." Jour. of Amer. Water Works Assoc., (November 1958)

all of the urban and 25, 50, and 75 percent of the rural residential populations for the years 1960, 1985, and 2010, respectively. The municipal-sanitary district population figures are then multiplied by the applicable daily per capita water use figure to obtain the total requirement. In event that water storage is required, both daily average and maximum daily average water requirements are given for use in determining reservoir storage capacity, i.e., the former value for supplies taken directly from storage and the latter for supplies taken downstream.

Based on studies of per capita water uses and apparent trends toward increased future per capita demands, the added annual unit increase in daily per capita municipal and district water uses is taken as 1.5 percent of the 1960 per capita figure. Maximum daily uses are obtained by adding 50 percent of the 1960 average gpcd as a constant to the future increases in average gpcd.

The county populations are divided into two categories, viz., farm and non-farm populations. The non-farm populations are further divided into three groups: rural residential, small towns, and urban. Municipal and district water requirement evaluations concern mainly the non-farm population groups, although it is known that farmers in certain areas haul significant amounts of water by tank truck from municipal systems. Area water requirements for municipal and district purposes include all urban populations, up to 75 percent of the rural residential populations, and certain small towns whose populations are expected to exceed 1,500 by the year 2010.

MUNICIPAL WATER SUPPLY DEMAND

The demand for municipal water supply is created by a number of special uses, i.e., domestic, commercial, public, fire, and industrial. The number and diversity of commercial business establishments, attractiveness to tourists and conventions, community habits, public policy with respect to civic duties, and size and type of industries within any city are peculiar to that city under consideration only. As a consequence, the municipal water demand computed on a per capita basis can be expected to vary among cities. Very often, for purposes of developing overall data on municipal water demand, writers have grouped cities by population brackets to determine unit water use. While this method furnishes a general idea of overall quantity of municipal demand, an engineer developing estimates of future water needs of a specific city would look primarily to the characteristics of the city under consideration.

The rates of municipal water use are affected by the size of the community, its location, habits and standard of living, availability of water, quality and cost of the water, the existence of sewers, extent and use of meters, pressure maintained on the distribution system, and other variables.

It should be pointed out that municipal uses are largely nonconsumptive and it can be expected that about 90 percent of the municipal demand will be returned to the water courses.

Domestic Use

The water used by the individual as a beverage is a very small quantity. The water used by the individual for bathing, laundry, toilet, kitchen, automobile washing, and yard use imposes larger demands for domestic purposes.

In projecting domestic water use, it is reasonable to believe that the standard of living will get progressively higher and that individuals will install water-using devices for convenience and comfort. Considering the use of existing water-using devices by apartment occupants only, a use of over 80 gpcd can be foreseen. For household or residence occupants, a use of 110 gpcd can be expected.

Commercial Use

This use is a composite of demands by many diversified business establishments such as hotels, motels, restaurants, shopping centers, bowling alleys, auto repair garages, auto service stations, and laundries. The type and number of such establishments will vary among communities and are dependent upon the population, as well as many other considerations of community character. A city such as Washington, D. C., which attracts tourists, conventions, and other visitors, would probably have a large water demand based on this consideration only. For instance, a restaurant will require about nine gallons of water per meal served, and a motel or hotel will have a demand of 70 gallons of water per day per guest. [1]

Observations made by others show water uses from 10,000 gallons per acre per day for a shopping center to over 90,000 gallons per acre per day for a complex mercantile district of a large city.

Public Use

Water used for public purposes includes street washing, park fountains, lawn watering, public buildings, public schools, and public hospitals. The rate of use will vary in communities according to the character of the city, and public policy reflecting the degree of civic pride. This water is often supplied to the city without remuneration to the municipal waterworks.

1 Thesis for Masters Degree - Phillip Searcy

Fire Protection

Protection against fire is an important function of a municipal waterworks. The total yearly quantity used for this purpose is small, but during a fire the rate of use is very great making it necessary to have large volumes of water available to meet this emergency.

Industrial Use

This use varies greatly according to the nature of the manufacturing and each case must be studied individually. Observations made by others show that the industrial use may range from zero to over 80 gpcd, based on the entire population of a city.

Waste

While wastage of water is not a use, it is certainly a consideration in developing a water supply adequate for the community, since such waste would appear within the gross per capita demand figure. Waste results from leakage aggravated by high pressures on the distribution system and carelessness or neglect by users.

Summary

In planning future water requirements for an area, it is believed that the prime consideration should be for public health and convenience. Estimates of future water requirements to meet all foreseeable needs should be generous. A rigid interpretation of historical records has in the past almost always resulted in an undersigned water system. In U. S. Senate Committee Print No. 7, page 11, of the Select Committee on National Water Resources, it was stated that the present 147 gpcd of average municipal use could conceivably increase to about 185 gpcd in 1980 and to 225 gpcd in the year 2000, with a possible leveling off thereafter.

It is believed that the best estimate of municipal demand in the Potomac River Basin can be developed by utilizing the historical record of each community and projecting increased use at a rate of 1.5 percent per year. Existing variations of the several uses as previously discussed are already built into historical records. It is recognized that an upper limit of per capita water use will develop; beyond the limit, use might be considered wasteful. Based on present knowledge, this upper limit will probably be in the range of 225-250 gpcd. Estimates of future demand are tempered by this judgment factor.

FUTURE INDUSTRIAL WATER REQUIREMENTS

Industrial water requirements are complicated by many factors affecting variability. Every product for which water is used in its manufacture requires differing quantities and qualities of water even

when identical product processing is utilized in similar plants. Significant losses of industrial water by evaporation or consumption in the product can occur. Water can frequently be re-used within the plant. Experience has shown that without ample water for industrial use, area development can be greatly curtailed. Water is one of the prime requisites in attracting new industry to a site, whether it be required for product manufacture or merely for sanitary use and fire protection. Since the ultimate objective of industry is increased production to meet promoted product demands, ample water must be available to satisfy continuously expanding needs.

Industrial uses of water in the United States during the 55-year period 1900 to 1955 increased fivefold or from 10 billion gallons per day in 1900 to 50 billion gallons per day in 1955. On the basis of this increase and various growth stimulating factors, estimates for the 25-year period 1955 to 1980 indicate that industrial uses will about double the 1955 figure. It is also noted that industrial uses of water in the United States were more than three times the municipal uses in 1900 and 1955, and are estimated to exceed the growing municipal uses estimated for 1980 by a factor of about 3.5.

The increase in industrial water use predicted by Picton (25-year period, 1955 to 1980) is an increase of 135 percent.[1] Woodward shows increases in industrial uses from 220 to 400 percent for the 25-year period from 1955 to 1980[2]. Differences in estimated future uses of industrial water by various authors appear to reflect viewpoints on water uses by newly established plants. Conservative estimates include only increased uses by existing industries.

Industrial water for purposes of this investigation is defined as water obtained from sources other than municipal or district supplies for use in the manufacture of a product or products, including in-plant uses for processing, cooling, and sanitation purposes. Industrial water requirements for use in connection with the steam generation of electricity are considered separately.

Total area industrial water requirements are computed to the year 2010 by expanding 1960 industrial uses at an annual rate consistent with economic evaluations prepared for the Basin by Department of Commerce, Office of Business Economics. Depending upon economic growth and predicted employment figures, annual industrial water requirement rates used for various areas may range from one to eight percent of 1960 uses (maximum increase of 400 percent by the year 2010). Areas where known industrial development is taking place but

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[1] W. L. Picton, "Water Use in the United States, 1900-1980," Business Service Bulletin, Department of Commerce, (March 1960).

[2] D. R. Woodward, "Availability of Water in the United States with Special Reference to Industrial Needs by 1980," Industrial College of the Armed Forces, Washington, D. C., 1956-1957.

for which industrial water requirements are not shown reflect types of industries requiring relatively small quantities of water, which are reflected in municipal and district water requirements.

FLOW REQUIREMENTS FOR QUALITY CONTROL

Natural water quality is altered by man in many ways. Materials of certain types and quantities when disposed of to stream water can upset the biological equilibrium of the stream, reduce recreational values, prevent use of stream water for municipal and industrial purposes and in some instances create serious nuisances and public health hazards, all of which become liabilities to the area affected.

Regulated stream flow has particularly great value during extreme drought periods when concentrations of nutrients and certain contaminantes are highest and where waste treatment for removal of oxygen demanding-substances is not sufficient to protect the receiving stream. Because improvements in stream quality by low flow augmentation would exceed improvement attained by conventional treatment, the value of increased flow would be equivalent to costs involved in attaining certain levels of tertiary treatment. However, it should be pointed out that tertiary treatment of wastes for reduction of oxygen-demanding substances, as presently known, would not produce the extent of improvement in other quality parameters as would be associated with an amount of low flow augmentation required to accomplish similar reductions in oxygen-demanding substances. Further, since it is not known to what extent future advance in waste treatment technology will exceed present conventional treatment capabilities, stream flow computations made in this study involve only the characteristics of waste effluents resulting from standard secondary municipal and equivalent industrial waste treatment as practiced today. Future municipal and industrial waste loads are obtained by determining the percentage of material that will remain after optimum treatment of the raw waste that are expected to be assocaited with projected populations and industrial growth.

Concentrations of biochemical oxygen demand (BOD) originating from municipal, industrial, and land runoff sources, together with the effects of these concentrations on dissolved oxygen (D.O.) levels in the stream, are used as the basis for minimum flow requirement determination. Whereas other pollutional parameters may exist on which flow requirements may be based, BOD concentrations and control of D.O. levels are used since this control is the primary intent of treatment works in the Potomac Basin.

In some instances, it was necessary to use water quality objectives established for control of substances not removed by conventional treatment. In this event, minimum stream flows were based on amounts of dilution required to control concentrations of these substances.

Where several waste loads are received in a given stream reach, the BOD loads from each source with allowances for assimilation between sources are compounded to a point or points of maximum stream loading. The required flow given is that which in combination with the BOD load and stream assimilative capacity at the point of maximum loading results in a desired level of dissolved oxygen at the lowest point of the dissolved oxygen sag curve. Purification factors and dissolved oxygen deficits used to compute maximum allowable BOD loads for various stream reaches are estimated from stream sampling data collected during the field survey.

METHOD OF COMPUTATION

Future water needs, waste effects on water quality and the uses that can be made of water storage projects for water supply and quality control in the various areas considered are based on sub-area population and employment figures developed by the Corps of Engineers in consultation with the Office of Business Economics and Public Health Service, as taken from the regional economic evaluation prepared by the Office of Business Economics (OBE). Requirements for municipal and industrial water uses represent estimates made by the Public Health Service on future per capita water demands and industrial water uses as applied to population and employment data projected for specific areas. Estimates were derived for future water quality resulting from specific water uses combined with anticipated waste treatment measures that are expected to be applied or required prior to returning the used water to the stream.

To determine the possible extent to which various reservoirs and associated flow increases could be utilized for water supply and water quality control, requirements for these purposes are established for a 50-year period or to the year 2010. These data are then compared with recorded minimum stream flows from which are determined the quantities and times at which stored water could be utilized.

Requirements for municipal and sanitary district water supply are combined by areas (municipal - district) to indicate demands by entire metropolitan populations regardless of the water distribution authority or authorities. Such areas are considered to contain urban, rural residential and in some cases small community populations plus related, commerical, institutional and small industrial water users.

The minimum stream flow data for design purposes associated with area water supply and quality control requirement evaluations shown in the reports were taken from data prepared by the Corps of Engineers in consultation with the Public Health Service. Many of these data represent computations involving flow data regressions

and adjustments by drainage areas to various water intake points or waste receiving reaches, based on minimum flows of record at key gaging stations for which sufficient historical data are available. The dependable unregulated stream flows used to determine needs for storage or additional stream flow for water supply throughout the Potomac Basin are taken to be the minimum flows of record and are referred to as the 1-day, 30-year stream flow. Main Stem Potomac River flow data take into account regulation of minimum flows from the Savage River Reservoir.

Needs for increased flow in combination with waste treatment for quality control in waste receiving reaches are based on minimum average consecutive 7-day recorded flows, having a frequency of occurence once in 10 years. This design minimum level of flow is applied to all points of waste discharge in order to maintain consistency in evaluation regulation needs in all areas of the Potomac Basin.

Where conventional secondary treatment is provided and natural flows are insufficient for assimilation the residual waste loads, flow regulation is an integral part of the overall water quality control program and storage projects are necessarily involved in providing this control. Benefits assignable to such projects for this purpose are considered to be equivalent to costs involved in constructing single-purpose alternate impoundments capable of providing similar dilution, or equivalent to costs of achieving the desired water quality by other means. Where industrial or thermo-electric cooling requirements would exceed natural stream flows and would utilize regulated flow, an additional benefit equivalent to the cost of alternate cooling methods is also assigned to flow regulation.

Individual benefit analyses are covered in Part IV for the North Branch and the rest of the basin is covered in Part VIII.

STREAMS AND AREAS EVALUATED

There were 43 population areas or stream reaches in the Potomac River Basin that were evaluated for need of new water supply sources and/or flow regulation as a supplement to waste treatment for control of stream quality.

By sub-basin areas they are as follows:

Sub-Basins	Covered in Part of Report	Number of Population Areas
North Branch Potomac	#IV	6
South Branch, Little Cacapon, Cacapon River	#VI	7
Conococheague & Antietam Creeks	#VI	6
Sleepy, Back, Opequon Creeks	#VI	4
Town, Sideling Hill, Tonoloway Licking Creeks	#VI	2
Catoctin Creek (Md.) & Monocacy River	#VI	5
Shenandoah River Basin	#V	10
Catoctin (Va.), Goose, Broad Run	#VI	2
Lower Potomac River & Estuary	#VII	1

These areas were classified as:

1. Those that had sufficient existing stream flow to meet all future requirements.
2. Those areas that would require flow regulation to meet their present or future needs for water supply and quality control.

Various means of meeting the requirements were investigated. It was found that either flows would have to be increased or the treated effluents piped to larger bodies of receiving waters, as treatment beyond conventional secondary or equivalent would be impractical of achievement at this time or within the foreseeable future.

Twenty-three multiple-purpose reservoirs are being considered by the Corps of Engineers to meet the flow requirements in the Potomac River Basin for water supply and quality control.

These sites are listed below for reference:

1. Stony River, near U. S. 50 Highway Bridge
2. North Branch at Bloomington
3. Savage River above existing reservoir
4. South Branch above Petersburg, West Virginia

5. Conococheague Creek Valley - West Branch
6. Conococheague Creek Valley - Back Creek
7. Conococheague Creek Valley - Main Stem
8. Opequon Creek near Winchester, Virginia
9. North Fork Shenandoah at Brock's Gap
10. Middle River below Staunton, Virginia
11. Monocacy River above Frederick, Maryland
12. Main Stem Potomac at River Bend, or
12a. Main Stem Potomac near Seneca Creek
13. Shenandoah River near Charles Town, West Virginia
14. Back Creek, West Virginia and Virginia
15. Licking Creek, Pennsylvania
16. Tonoloway Creek, Maryland and Pennsylvania
17. Sideling Hill Creek, Maryland
18. Town Creek, Maryland
19. South Branch near Springfield, West Virginia
20. South Fork Shenandoah above Front Royal
21. Little Cacapon River, West Virginia
22. Cacapon River, West Virginia
23. Patterson Creek, West Virginia

Small headwater impoundments have been considered where the areas of need cannot be served by major reservoirs due to their location.

The table entitled "Study Results" at the beginning of this Summary lists the stream reaches and areas of present and future water needs. The supplemental flow required above natural stream flow is presented with the benefit that would be derived from storage provided in multiple-purpose reservoirs.

It must be remembered that in all broad-planning schemes there will be local areas that do not quite fit into the picture. The major area requirements and future projections may all point to a most economical time of development in the future. However, a small but critical need within the major area may require positive action at the earliest possible date.

When all possibilities have been considered, it may be prudent to temporarily tolerate less desirable conditions for periods of low flow rather than expend resources for construction of interim measures that will be abandoned when the basin plan is implemented. It is considered that local situations such as this will have to be worked out on an economic feasibility plan at time of need.

PART I

WATER QUALITY STUDIES

FOREWORD

Part I of this report reviews the proposals made by the Public Health Service to the Corps of Engineers, Washington District, for the collection and evaluation of data, and reports progress relative to the Water Quality Program for the Potomac River Basin.

Sources and availability of existing water quality data are discussed. Recommendations for future activities, and procedures for achieving the desired objectives are included.

Part II of the report is a tabulation of water uses in the Potomac River Basin.

INTRODUCTION

On October 7, 1957, the Public Health Service submitted to the Corps of Engineers, Washington District, a report entitled, "Proposal for Initial Report on Water Quality Program for the Potomac River Basin Review Report," in which it was proposed that the Public Health Service prepare, during the remainder of Fiscal Year 1958, an initial report based on available data and including a proposal for additional work necessary for a final report on water quality in the Potomac River Basin.

Approval of this proposal by the Corps of Engineers was indicated in a letter dated October 29, 1957. The same letter also authorized the Service to proceed with the work outlined in the proposal.

On December 3, 1957, the Public Health Service submitted to the Corps of Engineers a proposal for completing a comprehensive study of water quality in the Potomac River Basin during Fiscal Years 1958, 1959, 1960, and 1961. The Corps of Engineers approved this proposal by letter dated June 6, 1958.

SCOPE OF FISCAL YEAR 1958 ACTIVITIES

The proposals listed above indicated that the scope of Fiscal Year 1958 activities would include:

A. Collection of available data from Federal, State, and local agencies.

B. A start on analyses of available data, with emphasis on the Washington Metropolitan Area.

C. Completion of a preliminary report to include, insofar as possible, evaluation of existing water quality in problem areas; special consideration of the Washington Metropolitan Area problem; catalog of additional data needed for the final report; a schedule of special studies required for necessary additional data; and, if necessary, a revised estimate of cost of special studies and completion of the final report.

COLLECTION OF DATA

During Fiscal Year 1958, such data on the preceding items as had been developed by others were collected and evaluated in order to avoid duplication of work, and to prepare recommendations as to additional work required to develop needed data. Visits were made to the several State and regional agencies for the purpose of discussing the proposed comprehensive water quality and water use study with each agency, to obtain copies of all applicable data and reports previously developed by others, and to inquire as to any specific problem areas. Acknowledgment is made of the cooperation of the following agencies in furnishing information pertinent to the study:

Maryland Department of Health
Maryland Water Pollution Control Commission
Maryland Water Resources Commission
Pennsylvania Department of Health
Virginia State Department of Health
Virginia State Water Control Board
West Virginia State Water Commission
Interstate Commission on the Potomac River Basin
District of Columbia Blue Plains Sewage Treatment Plant

An invaluable record of water quality in the tidewater Potomac River from Three Sisters Island to Fort Washington was available from the District of Columbia Blue Plains Sewage Treatment Plant. A routine river sampling and analysis program has been conducted, without break, since September 22, 1937. Copies of all analytical results through 1956 previously had been made available to the Public Health Service. It was necessary, however, to obtain additional data and to obtain time of day of previous sample collections in order to correlate magnitude of determinations with tidal variations. Times of sample collections were available for the periods February 10, 1943 to November 25, 1945; and September 30, 1953 to August 12, 1957. Times of sample collections along with other pertinent data were placed in a computer program to convert the sampled position to the low tide slack position in order to compare all data at the same tidal position. Whether or not these data can be adequately correlated remains to be proven and will require additional statistical analyses. The extent of additional sampling in the tidal area necessary to supplement existing data will be determined by these analyses.

Previous reports developed on the subject of the Potomac River were assembled but have not yet been assimilated. These reports include the following:

"Hygienic Laboratory," Public Health Service, 1913-1914.
"Bacteriological Study," Public Health Service, 1925.
"Study of Disposal of Sewage," Public Health Service, 1932.
"Benefits of Low Flow Augmentation," Public Health Service, 1944.
"Water Pollution in the Potomac River Basin," Interstate Commission on the Potomac River Basin, 1954.
"A Clean Potomac River in the Washington Metropolitan Area," Interstate Commission on the Potomac River Basin, 1957.

DISCUSSION OF DATA

The data received from the several agencies on water uses have been tabulated and arranged by tributary name, in sequence of occurrence from the upper extremities of the basin to the mouth of the Potomac River, and are included as Part II of this report. Preceding the tabulation is an explanation of the headings and subscripts used, and a Key to Symbols which describes the treatment of water supplies, sewage, and industrial wastes.

The data indicate that little stream survey work has been performed by the several States in recent years. Consequently, there is only very limited water quality data available. Virginia had made an extensive stream survey on the South River in the vicinity of Waynesboro, Virginia, in the summer of 1957. Pennsylvania had conducted a stream survey of Conococheague Creek in 1951. In recent years, neither Maryland nor West Virginia has conducted stream surveys in the basin. Copies of data from these studies, while not included in this report, will be of value to future studies necessary to provide a true picture of water quality in the Potomac River and its tributaries. The data collected in Fiscal Year 1958 will, however, be included as a part of future studies.

While each State had records of sources of wastes and known problem areas, there are differences between State records and actual situations, probably due to changes made in the field and a time lag in recording such changes in State records.

An examination of the data pertaining to the Washington Metropolitan Area, although not yet complete, indicates that the information currently available is not sufficient to adequately interpret the present effects of tidal action on pollution in the Washington Metropolitan Area, nor to predict the probable effects of low-flow augmentation from upstream reservoirs. Additional stream studies will be needed to obtain the data necessary for making the above interpretations and predictions. Personnel well versed in the study of tidal currents will be required for this work.

CONCLUSIONS

On the basis of the information collected and analyzed during Fiscal Year 1958, it is concluded that:

A. While all States have data on water uses in the basin, in some cases the official records available have not yet been brought up to date. Up-dating of such information is necessary for evaluation of a reservoir development program.

B. With the few exceptions previously noted, there are no recent water quality data available upon which to base any evaluation of impact of a reservoir development program.

C. The study of the portion of the Potomac River in tidewater in the Washington, D. C. Metropolitan Area is complex and will require special skills in order to evaluate effects of tidewater on pollution and the significance of low flow augmentation from upstream reservoirs. Considerable work is now under way in assembling and analyzing data preliminary to determination of additional field studies required and the development of study techniques applicable to tidewater conditions.

D. The study of current and proposed future use of the Potomac River as a source of public water supply will be a large task and will require a concentrated effort of at least one engineer for about a year.

RECOMMENDATIONS

In order to complete the comprehensive study of water quality, it is recommended that:

A. During Fiscal Year 1959 the following work should be undertaken:

   1. Stream surveys should be conducted on the main stem of the Potomac River and its tributaries in that portion of the basin from tidewater to Paw Paw, West Virginia, in order to obtain data necessary for evaluation of water quality and water uses in the basin with particular reference to public water supplies. At such time as the Corps of Engineers determines exact locations of reservoir sites it may be necessary to supplement information gained in such a survey with additional field studies.

2. All water users within the basin should be contacted. Current data on water use, treatment, and sources of wastes should be developed and estimates of future water uses, need of treatment, and magnitudes of waste loads should be obtained from the water users.

3. A field survey team should be organized to conduct a field study of the water quality of the Potomac River and each of its tributaries.

4. The analyses of the data pertaining to tidewater in Washington, D. C. Metropolitan Area should be continued to establish a firm basis for future stream studies in that portion of the basin.

5. An engineer skilled in pollution studies should be trained in the techniques of oceanography in order to better understand the Washington, D. C. Metropolitan Area situation. This engineer will then have the necessary skills required for the study of the tidewater Potomac in the Washington area.

B. As a part of any Fiscal Year 1960 program, the service of one engineer should be included to concentrate on a study of current and proposed future use of the Potomac River as a source of public water supply.

C. The schedules established for the study of the Potomac River Basin for Fiscal Years 1959, 1960, and 1961, (as set forth in the proposal for completing a comprehensive study of water quality in the basin, submitted to the Corps of Engineers on December 3, 1957, and approved by the Corps of Engineers on June 6, 1958) should be carried to completion.

PART II

TABULATION OF DATA ON WATER USES
IN THE POTOMAC RIVER BASIN

COMPILATION OF EXISTING DATA ON WATER USES AND QUALITY

I. Sub-basin
   A. Municipality or Industry
      1. Location
         a. County
         b. State
         c. River Mile
      2. Population or number of employees
      3. Water
         a. Source of supply
         b. Quantity used or population served
         c. Use
         d. Treatment
      4. Wastes
         a. Type
         b. Quantity
         c. BOD (population equivalent)
         d. Treatment
         e. Receiving stream
      5. Water quality data available

EXPLANATION OF TABULATION AND SUPERSCRIPTS

LOCATION

Municipality or Industry

An asterisk signifies that the entry was taken from the report, "Recommendations as to Policy, Legislation and Methods of Financing for the Preservation of the Water Supply Resources of the State of Maryland," Water Resources Commission of Maryland, January 1933.

Entries other than municipalities are followed by the nearest municipality with counties enclosed in parentheses.

County - State

The county in which the water use occurs is given, even though the nearest municipality may be in another county.

River Mile

Miles to Mouth, "Potomac," signifies that the distance is measured from the location to the mouth of the Potomac River at Chesapeake Bay, while Miles to Mouth, "Tributary" signifies

that the distance is measured from the location to the junction of the tributary streams with the Potomac River.

Population or Employees

Populations were taken from the 1950 Census unless more recent data were available.

WATER SUPPLY

Population Served

An asterisk signifies that the entry is the design population and the population served is unknown.

Quantity Used

An asterisk signifies that the entry is the design flow and the actual quantity used is unknown.

Use of Water

For municipalities it is assumed that the use of water is for domestic purposes, along with possible industrial uses, and no entry is made.

Treatment

See Key to Symbols.

WASTE DISCHARGE

Quantity Discharged

An asterisk signifies that the entry is the design flow and the actual quantity discharged is unknown.

Population Equivalent BOD Discharged

It is assumed that 0.17 pounds of 5-day 20°C. biochemical oxygen demand (BOD) constitutes one population equivalent.

Treatment

See Key to Symbols.

Population Served (Sewerage)

An asterisk signifies that the entry is the design population and the population served is unknown.

KEY TO SYMBOLS

Water Supply - Treatment

Type of Plant - P - Purification
H - Softening
I - Iron or Manganese removal
D - Disinfection

Treatment or Device - A - Aeration

Ac . . contact beds or trays, coke or other material
Am . . patented aerator
As . . spray aerator
At . . overflow trays cascade or other splashaerator
Ao . . other type aerator

C - Chemical dosage for coagulation or softening

Ca . . alum
Ci . . iron salts
Cl . . lime
Cs . . soda ash
Ct . . activated silica
Co . . other coagulant

D - Disinfection

Dc . . chlorine gas
Dd . . dechlorination
Dh . . hypochlorites
Ds . . free residual chlorine
Dx . . chlorine dioxide
Dz . . ozone
Do . . other means

F - Filters

Fa . . anthrafilt
Fc . . roughing or contact
Fd . . Diatomaceous earth
Fg . . gravity (slow)
Fp . . pressure
Fr . . gravity (rapid)
Fs . . sand
Fz . . zeolite

K - Chemical dosage for corrosion correction or water stabilization

Kc . . phosphate compounds
Kg . . chlorine gas
Kh . . hypochlorite
Ko . . sodium silicate
Kp . . alkali feed for pH adjustment

M - Mixing device or tank

Ma . . air agitation
Mb . . baffle mix
Mh . . hydraulic (standing wave flume)
Mi . . injection or pump suction application
Mp . . slow mechanical mix
Ms . . patented sludge blanket
Mt . . rapid mechanical mix

(MtpsSv) "Liquon Sludge Contact Reactor"; "Accelator"; "Precipitator"

N - Ammoniation

Nc . . ammonium compound
Ng . . ammonia gas

R - Recarbonation

S - Sedimentation

Sb . . baffled basins (other than inlet or outlet baffles)
Sc . . covered basins (other than housed)
Sm . . mechanical sludge removal
So . . open basin (may be inside plant building)

S - Sedimentation (continued)

Sv . . up and flow cylindrical tanks

(MtpsSv) "Liquon Reactor"; "Accelator"; "Precipitator"

T - Chemical taste and odor control

Tc . . activated carbon
Td . . chlorine dioxide
Ts . . sulfur dioxide
Tz . . ozone
To . . other

V - Fluoride adjustment

Va . . hydrofluosilicic acid
Vs . . sodium silicofluoride
Vt . . sodium fluoride
Vo . . other fluorides
Ve . . ammonium silicofluoride
$V_{1.2}$ . . 1.2 ppm natural fluorides

Waste Discharge - Treatment

The principal treatment devices and methods are identified by capital letters and are further described by the subsequent lower case letters. In general, the symbols will be arranged in the order of sewage flow, with sludge treatment symbols following thereafter. Combination units performing more than one function in a single structure are denoted by enclosing the appropriate symbols in parantheses. Enclosures in brackets indicate parallel or alternate operation. Chlorination, where used, is noted only once for each plant, whether or not actual application is made at more than one point.

A ----- Aeration

Aa -- Activated sludge, diffused air aeration
Ac -- Contact aerators
Am -- Activated sludge, mechanical aeration
Ap -- Aeration, plain, without sludge return

B ----- Sludge beds

Bo -- Open
Bc -- Glass covered

C ----- Settling tanks

Ci -- two story (Imhoff)
Cm -- mechanically equipped
Cp -- plain, hopper bottom or intermittently drained for cleaning
Cs -- septic tank
Ct -- multiple tray, mechanically equipped

D ----- Digester, separate sludge

Dc -- with cover (fixed if not otherwise specified)
D(cg)-gasometer in fixed cover
De -- gas used in engines (heat usually recovered)
Df -- with floating cover
Dg -- with gasometer cover
Dh -- gas used in heating
Dm -- stirring mechanism
Do -- open top
Dp -- unheated
Dr -- heated
Ds -- gas storage in separate holder
Dt -- stage digestion

E ----- Chlorination

Ec -- with contact tank
Eg -- by chlorine gas
Eh -- by hypochlorite

F ----- Filters

Fc -- contact beds
Fm -- magnetite (straining)
Fo -- roughing filters
Fr -- rapid sand or other sand straining
Fs -- intermittent sand
Ft -- trickling (no further details)
Fth - high capacity
Ft1h- high capacity, single stage
Ft2h- high capacity, two stage
Ftn - fixed nozzle, standard capacity
Ftr - rotary distributor, standard capacity
Ftt - traveling distributor, standard capacity

G ----- Grit chambers

Gh -- without continuous removal mechanism
Gm -- with continuous removal mechanism
Gp -- grit pocket at screen chamber
Gw -- separate grit washing device

H ----- Sludge storage tanks (not second stage digestion units)

Hc -- covered
Hm -- with stirring or concentrating mechanism
Ho -- open

I ----- Sewage application to land

Ic -- with cropping
Ip -- percolation beds
Is -- sub-surface application
Iu -- land underdrained

K ----- Chemical treatment - Flocculation. Chemical treatment-type units or equipment not necessarily complete or operated as chemical treatment

Ka -- flocculation tank, air agitation
Kc -- chemicals used
Km -- flocculation tank, mechanical agitation
Kx -- no chemicals used

L ----- Lagoons

Le -- evaporation lagoons
Lo -- oxidation lagoons or ponds
Lp -- lagoon for settling of sewage
Ls -- sludge lagoons - not for treatment of sewage

O ----- Grease removal or skimming tanks - not incidental to settling tanks

Oa -- aerated tank (diffused air)
Om -- mechanically equipped tank

S ----- Screens

Sc -- comminutor (screenings ground in sewage stream)
Si -- intermediate screens (1/8" to 1/2" openings)
Sf -- fine screen (less than 1/8" openings)
Sg -- screenings ground in separate grinder and returned to sewage flow
Sh -- bar rack (1/2" to 2" openings) hand cleaned
Sm -- bar rack (1/2" to 2" openings) mechanically cleaned
Sr -- coarse rank (openings over 2")
St -- garbage ground at plant and added to sewage flow

T ----- Sludge thickener

Tc -- covered
Tm -- stirring mechanism
To -- open top

V ----- Mechanical sludge dewatering

Vc -- sludge centrifuge
Vv -- rotary vacuum filter
Vo -- other

X ----- Sludge disposal

Xb -- barged to sea
Xd -- used for fertilizer
Xf -- burned for fuel
Xn -- incinerated
Xp -- used for fill

Z ----- Sludge conditioning

Za -- chemicals used, alum
Zc -- chemicals used (unidentified)
Zi -- chemicals used, iron salt
Zl -- chemicals used, lime
Zx -- no chemicals used
Zy -- elutriation

INDUSTRIAL WASTE TREATMENT OPERATIONS AND PROCESSES

The following numerical coding is used for the description of those situations in which the treatment of industrial wastes cannot be satisfactorily or fully described by use of the foregoing symbols alone. The preceding letter symbols and the following numerical coding are used in combination when necessary, although either may be used alone.

1. Centrifugation

Defn. Separation of solids and fluids of different densisities or separation of the nature of filtration in an apparatus rotating at high speed.

Ex. Separation of wool grease from acid cracked wool scouring liquor in a centrifuge.

2. Distillation and Stripping

Defn. Distillation is a separation of volatile liquids by utilizing the differences in their volatilities. Stripping is a separation of a volatile material from a less volatile or non-volatile liquid with the aid of a stream of air or other gas.

Ex. Kopper's process for distilling phenol from ammonia-still liquor.

3. Emulsion Breaking

Defn. Separation of two liquids in colloidal suspension.

Ex. Passing oil in water of waste emulsion from the treatment of light and lubricating oils between electrodes to charge the particles and cause separation.

4. Evaporation

Defn. Volatilization of water or other material from non-volatile residue.

Ex. Concentration of Steffens waste from beet sugar manufacture in multiple effect evaporators.

5. Extraction

Defn. Transferral of a constituent of a solid or liquid to another liquid (the solvent).

Ex. Extraction of phenol from ammoniacal liquor with benzene.

6. Filtration

Defn. Separation of a heterogeneous mixture of a fluid and particles of solid by a filter medium which permits the flow of a fluid but retains the particles of solid.

Ex. Use of save-alls for the removal of fiber from white water in the pulp and paper industry. Filter presses for removal of lanolin from wool scouring wastes.

7. Flotation

Defn. Separation of a material by floating at or on the surface of a liquid.

Ex. Flotation save-alls for removal of fiber and other suspended solids from white water.

8. Neutralization

Defn. Addition of acids or bases to basic or acidic material so that it is no longer acidic or basic, to get a pH value of about 7.0.

Ex. Neutralization of acid wastes resulting from the manufacture of nitro-cellulose with dolomitic lime.

9. Oxidation - Chemical

Defn. Changing an element from a lower to a higher positive valance by chemical action.

Ex. Chlorination of cyanides in alkaline solution.

10. Regulated Discharge

Defn. The procedure or actions involved in artificially controlling the flow of liquid wastes so that their discharge at a specific time or times will serve a specified purpose or objective.

Ex. Lagooning of cannery wastes, with discharge to the stream in small volumes over long periods of time when temperatures are low and stream flows high.

11. Waste Prevention Measures

Satisfactory efforts by industry to prevent waste materials resulting from industrial operations from entering the sewers.

This group also includes efforts by industries not sewered, to prevent waste materials from entering a watercourse by other means.

Practices of disposal other than those described by codes are included in this group.

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
North Branch	285				
*Davis Coal & Coke Co., Kempton, Md. (Garrett)				N. Br. Potomac R.	
Buffalo Creek, Md.		87			
Fairfax Coal Washery, Bayard, W. Va. (Grant)					
Savage River, Md.		54			
Frostburg, Md. (Allegany)			6,876	Savage R., Piney Cr., Wells and Springs	
Luke, Md. (Allegany)		53	820	W. Va. Pulp & Paper Co. (from N. Br.)	
West Virginia Pulp & Paper Co.		53	1,657	N. Br., Potomac R. and Savage R. (Supplement to N. Br. Potomac R.)	
Piedmont, W. Va. (Mineral)		51	2,565	Savage R.	2,700
Georges Creek, Md.		51			
Borden Shaft, Md. (Allegany)			192	Staubs Run of Georges Cr.	
*Consolidation Coal Co., Lord, Md. (Allegany)			60	Georges Cr.	
Midland, Md. (Allegany)			889	Lonaconing, Md.	
Lonaconing, Md. (Allegany)			2,289	Jackson Run, Elklick Run, Koontz Run, of Georges Cr.	
Barton, Md. (Allegany)			695	Wells; Bartlett Run of Georges Cr.	
Westernport, Md. (Allegany)		51	3,431	Savage R.	
New Creek, W. Va.		46			
Keyser, W. Va. (Mineral)		46	6,347	Springs and New Cr.	7,000
Royal Dairy Co.		46			
Mason Dairy, Cresaptown, Md. (Allegany)					
Cellanese Corp. of America, Amcelle, Md. (Allegany)		27		N. Br., Potomac R.	

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10-3)	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10-3)	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
125								
			Coal Washing				So	Buffalo Cr. of N. Br., Potomac R.
		FKNDc			5,000			Georges Cr. and Jennings Run
		AFKDc			900	900	None	N. Br., Potomac R.
40,000		F, Chemi-cal	Magazine newsprint production	40,000		300,000	ScCm BoXp, 11	N. Br., Potomac R.
325		CSFD			2,400		None	N. Br., Potomac R.
		None						
5								
					620			Georges Cr.
		Dc, Dh, Dh			1,880			Georges Cr.
		Dh; Dh			480			Georges Cr.
		FKDc			3,500	3,500	None	N. Br., Potomac R.
500		SFD			4,650		None	N. Br., Potomac R.
							None	
			Dairy				11	Unnamed trib. of N. Br., Potomac R.
40,000	Cooling water	8	Cellulose acetate fiber manu-facture	3,600		59,000	11	N. Br., Potomac R.

Name and Location of Industry or Municipality	Miles from Mouth: Potomac	Miles from Mouth: Tributary	Population or Employees	WATER: Source of Supply	WATER: Population Served
Potomac River					
North Branch (continued)	285				
Potomac Edison Power Co., Amcelle, Md. (Allegany)		27		N. Br. Potomac R.	
Wills Creek, Md.		22			
Hyndman, Pa. (Bedford)			1,322	Laurel Run of Little Wills Cr. of Wills Cr.	1,350
Cumberland Cement and Sand Co., Cumberland, Md. (Allegany)					
*Cumberland Coal Co. Barrellville, Md. (Allegany)			200	Wills Cr.	
Cumberland, Md. (Allegany)		22	37,679	Evitts Cr.	
Pittsburgh Plate Glass Co.			600	N. Br., Potomac R. and Cumberland, Md.	
Potomac Edison Power Co.				N. Br., Potomac R.	
Potomac Edison Power Co.				N. Br., Potomac R.	
Kelley Springfield Tire Co.				N. Br., Potomac R.	
*Union Tanning Co.					
Cumberland Laundry Co.					
N. & G. Taylor Co.					
Ridgely, W. Va. (Mineral)		19	1,754	Cumberland, Md.	1,972
Evitts Creek, Md.					
Evitts Cr. Water Co., Pa. (Bedford)				Evitts Cr.	43,000 in Md. (including Cumberland) 15,000 in Pa.
Koppers Co., Green Spring, W. Va. (Hampshire)		2	135		

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
	Power plant cooling water (10,000 KW)							
100		None			1,322		None	Little Wills Cr.
			Silt	288			L	Wills Cr.
5								
12,500		FDcN			45,000	45,000	SmCh CmDm crts Bo	N. Br., Potomac R.
2,000			Silt; Sanitary sewage				L;Pri. for san. sewage	N. Br., Potomac R.
43,200	Cooling water (30,000 kw)	Dc	Cooling water			None		N. Br., Potomac R.
28,800	Cooling water (9,000 kw)		Cooling water			None		N. Br., Potomac R.
10,000 to 15,000	Cooling water	None	Cooling water			None		N. Br., Potomac R.
				119				N. Br., Potomac R.
				25				N. Br., Potomac R.
				100				N. Br., Potomac R.
				38	1,000			N. Br., Potomac R.
*18,000		CalTc MbFa DcVaNg						
							F	N. Br., Potomac R.

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
South Branch, W. Va.	285				
Franklin, W. Va. (Pendleton)			777	Springs	600
Petersburg, W. Va. (Grant)		69	1,898	S. Br., Potomac R. and deep well	2,000
Petersburg Tanning Co.					
*Community Power Co.				S. Br., Potomac R.	
Moorefield, W. Va. (Hardy)		57	1,405	S. F. of S. Br., Potomac R.	1,500
Loewengart and Co.				Moorefield, W. Va. and springs	
Rockingham Poultry Co.			125	Moorefield, W. Va.	
Romney, W. Va. (Hampshire)			2,059	S. Br., Potomac R.	2,500
School for Deaf and Blind				S. Br., Potomac R.	400
Cacapon River, W. Va.	280				
Lost River State Park (Hardy)			50		
*Northern Virginia Power Co., (Morgan)				Cacapon R.	
Tonoloway Creek, Md.	237				
*Cyrus S. Johnson Hydro-electric plant, Pa. (Fulton)				Trib. of Tonoloway Cr.	
Warm Springs Run, W. Va.	236				
Berkeley Springs, W. Va. (Morgan)			1,199		750
Aulabaugh Bros., Inc.				Well	
Pennsylvania Sand Glass Co.			225	Warm Springs Run	

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treatment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treatment	Receiving Stream
50		D					Pri.	S. Br., Potomac R.
200		Accelator, CFD			1,000		None	S. Br., Potomac R.
							CLp	S. Br., Potomac R.
	Hydro-electric plant (565 HP)							
400		CSFD			950			S. Br., Potomac R.
100 (city) 2 (springs)	Tanning		Tannery	100			ScLX	S. F. of S. Br., Potomac R.
100 to 170			Poultry processing	100 to 170			S,11	S. F. of S. Br., Potomac R.
150		CSFD			1,800	360	ShCi FtnEcg CpBo	Big Run of S. Br., Potomac R.
40		FD						
					780		CsIs	Cacapon R.
	Hydro-electric plant (1,120 HP)							
	Hydro-electric plant							
185		D			700		None	Warm Springs Run
18 (during season)	Tomato canning	None	Tomato waste	18 (during season)			None	Warm Springs Run
1,450 to 2,150	Sand washing	None	Inorganic	1,450 to 2,150			None	Warm Springs Run

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Conococheague Creek, Md.	211				
Scotland Orphanage, Pa. (Franklin)				Burgner Springs of Little Antietam Cr.	850
Chambersburg, Pa. (Franklin)		53	17,212	Hoosic Run & Birch Run of Conococheague Cr.	18,500
H. J. Heinz Co.				Chambersburg, Pa.	
Chambersburg Steam Generating Plant				Conococheague Cr.	
Greencastle, Pa. (Franklin)		32	2,661	Springs	2,800
Greencastle Packing Co.			42 (460 at peak)	Greencastle, Pa.	
Mercersburg, Pa. (Franklin)			1,613	Drilled well, spring, and Buck Run of W. Br. of Conococheague Cr.	2,500
Lowengart & Co.			240	Wells and Mercersburg, Pa.	
S. G. Dixon State TB Hospital, Pa., (Franklin)				Springs and W. Br. of Antietam Cr.	1,700
U. S. Paper Mills, Inc., Pa. (Franklin)				E. Br. of Conococheague Cr.	
Path Valley Esso Service Station, Pa. (Franklin)				Drilled wells	20 to 30
W. D. Byron & Sons of Maryland, Inc., Williamsport, Md. (Washington)			160	Conococheague Cr. and springs	80 (creek) 160 (springs)
Kemps Mill Tavern, Williamsport, Md. (Washington)					

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treatment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treatment	Receiving Stream
100		Dc		100			CiFtn CpEgc Bo	Conococheague Cr.
3,000		DcKp		1,500	18,500		ScAp ChCm Ft2hCm EcgDch mrDftBc	Conococheague Cr.
500	Canning		Vegetable canning	500			SiIc	East Br. of Conococheague Cr.
2,500	Cooling water for power generation							
480		Dh		400	3,500	5,150	ScCmFt lhCmEgc DchmrBo	Unnamed Run of Conococheague Cr.
12	Frozen foods		Potato waste	12			SiIc	None
220		Dh		185	2,400		ScCm Ftlh CmEgc DchmPBo	Steiger Run of W. Br. of Conococheague Cr.
220	Tanning	None	Tannery	220			CmLo Ls	Steiger Run of W. Br. of Conococheague Cr.
340		ClDc		300	1,700		ScCm Dchrt AmCm EgBc	Rocky Mountain Run of Conococheague Cr.
	Paper	None	Shower water				11	E. Br. of Conococheague Cr.
		Dh		20 to 30			ScCim Ft2h EchBc	Unnamed Cr. of W. Br. of Conococheague Cr.
	Tanning, cooling	None	Tannery	55		8,000	ScpL	Conococheague Cr.
					100		None	Conococheague Cr.

POTOMAC RIVER BASIN STUDIES

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Opequon Creek, Md.	202				
Winchester, Va. (Frederick)			12,095	N. F., Shenandoah R.	16,000
O'Sullivan Rubber Co.			500	Abrams Cr. of Opequon Cr.	
American Brakeshoe Co.					
*Virginia Woolen Mills					
Winchester Woolen Mills					
*Shenandoah Box Board Co.					
Virginia Woolen Co., Middleway, W. Va. (Jefferson)				Springs	
Inwood, W. Va. (Berkeley)			480	Wells	400
Musselman Canning Co.					
Martinsburg, W. Va. (Berkeley)		5	15,621	Springs	18,000
National Fruit Products Co.					
Standard Lime and Stone Co.			600	Springs	
Blair Limestone Co., Blairton, W. Va. (Berkeley)					
Antietam Creek, Md.	180				
Fayetteville, Pa. (Franklin)			810	Cold Spring Run of Little Antietam Cr.	3,000
Mont Alto, Pa. (Franklin)			984	Pearl of the Park Spring of Rattlesnake Cr.	990
E.U.B. Orphanage, Pa. (Franklin)				Drilled well	220
Waynesboro, Pa. (Franklin)			10,334	Little Antietam Cr., Rattlesnake Cr.	9,800
Camp Ritchie (U.S. Army), Md., (Washington)		29			
Potomac Edison Co., Security, Md. (Washington)				Antietam Cr.	

POTOMAC RIVER BASIN STUDIES

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
2,810		Dc					Pri., Sec., E	Abrams Cr. of Opequon Cr.
440							Pri., E	Abrams Cr. of Opequon Cr.
							Pri., Sec.	Abrams Cr. of Opequon Cr.
								Opequon Cr.
								Opequon Cr.
								Opequon Cr.
							Com-plete	Opequon Cr.
21		D						Opequon Cr.
						9,000	L	Opequon Cr.
3,000		DV			18,000	12,000	SbCl Ftn CpBo	Opequon Cr. Tuscarora Cr. Potomac R.
							SF	Tuscarora Cr. of Opequon Cr.
140		F						
							Set-tling	Opequon Cr.
65		Dh					On lot disposal	
50		Dh					On lot disposal	
13		Dh			350		SbCl Ftn CpEhBo	Little Antietam Cr.
2,020		DcNg		800	10,500*		SmCm Ftr CpEBo	E. Br. of Little Antietam Cr.
								Antietam Cr.
18,600	Cooling water for power generation	None	Fly ash				C	Marsh Run of Antietam Cr.

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Antietam Creek, Md. (continued)	180				
North American Cement Co., Security, Md. (Washington)				Antietam Cr.	
Hagerstown, Md. (Washington)		24	36,260	Raven Rock & Warner Gap; Potomac R.	41,000
Western Maryland Railroad Co.			2,000		
Fairchild Aircraft Co.			6,000 to 9,000	Hagerstown, Pa.	
Municipal Electric Light Plant				Antietam Cr.	
*Maryland State Penal Farm, Roxbury, Md. (Washington)			75		
Maryland State Reformatory for Males, Breathedsville, Md. (Washington)			400		
Boonsboro, Md. (Washington)				Springs	1,500
Mullendore Slaughter House					
*Maryland Light & Power Co.				Antietam Cr.	
Shenandoah River, W. Va.	171				
North Fork, Va.		55			
Broadway, Va. (Rockingham)			561	N. F., Shenandoah R.	600

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
18,600	Cooling water for power generation		K_2CO_3, fly ash				L	Antietam Cr.
6,500		DcNKV; FKDcV		*6,000	33,000	5,700	SmGh CmAa CmDm crts ZyVvBo	Antietam Cr.
	Wash water		Wash water & degreasing	375			7,8	Antietam Cr.
630	Domestic and chrome plating		Domestic and chrome plating	165 (Domestic)			ScCf trCm FaEg DfhBo	Marsh Run of Antietam Cr.
				465 (Plant)			None	
1,580	Cooling water for power generation	None					None	Antietam Cr.
							CD	Antietam Cr.
					400	260	SmCm FtrCm DmopBo	Antietam Cr.
50		D			None			
	Floor wash		Slaughter-house floor washings				11Is	Unnamed trib. of Little Antietam Cr.
	Hydro-elec. plant (360 HP)							
144		FD						Linville Cr. of N.F., Shenandoah

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Shenandoah River, W. Va.	171				
North Fork, Va. (continued)		55			
Timberville, Va. (Rockingham)			271	N. F., Shenandoah R.	
*Virginia Public Service Co.				N. F., Shenandoah R.	
Food Processors Water Cooperative				N. F., Shenandoah R.	
Valley Housing Corporation, Va. (Rockingham)					
New Market, Va. (Shenandoah)			701	Smith Cr. of N. F., Shenandoah R.	1,000
*Virginia Public Service Co.				N. F., Shenandoah R.	
Orkney Springs, Va. (Shenandoah)					
Mount Jackson, Va. (Shenandoah)			732	Trib. of N. F., Shenandoah R.	800
Edinburg, Va. (Shenandoah)			533		
*Virginia Public Service Co.				N. F., Shenandoah R.	
Woodstock, Va. (Shenandoah)			1,816		
*Virginia Public Service Co.				N. F., Shenandoah R.	
Strasburg, Va. (Shenandoah)			2,022	N. F., Shenandoah R.	2,000
Winchester, Va. (Frederick)			12,095	N. F., Shenandoah R.	16,000
South Fork		55			
Waynesboro, Va. (Augusta)			12,357	Springs	
Crompton Shenandoah Co.					

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treatment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treatment	Receiving Stream
				15			None	N.F., Shenandoah
	Hydro-electric plant (110 HP)							
500		FD						
					300		Pri., [illegible]	N.F., Shenandoah
				120			None	Smith Cr. of N.F., Shenandoah
1,500	Cooling water for steam power							
							Pri.	Stoney Cr. of N.F., Shenandoah
				81			None	Mill Cr. of N.F., Shenandoah
				60			None	Trib. of N.F., Shenandoah
	Hydro-electric plant (220 HP)							
				182			None	N.F., Shenandoah
	Hydro-electric plant (360 HP)							
				200			None	N.F., Shenandoah
2,810		DC					Pri., Sec., E	Abrams Cr. of Opequon Cr.
1,410					20,000			South R. of S.F., Shenandoah
				2,200				S.F., Shenandoah

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Shenandoah River, W. Va.	171				
South Fork		55			
Waynesboro, Va. (Augusta) (continued)					
E. I. dePont de Nemours and Co., Inc.					
*Edison General Electric Co.					
Stehlis Silk Mills					
Staunton, Va. (Augusta)			19,927	Mountain Stream of North R. and spring	25,000
American Safety Razor Co., Verona, Va. (Augusta)				Middle R. of S. F., Shenandoah	1,200
Western State Hospital, Va. (Augusta)					
Woodrow Wilson School, Va. (Augusta)					
Skyland-Swannanoa, Va. (Augusta)					
Greenville State Welfare Camp, Va. (Augusta)					
Verona Sanitary District, Va. (Augusta)					
Bridgewater, Va. (Rockingham)			1,537	Springs	
*North River Electric Co.				S. F., Shenandoah	
Dayton, Va. (Rockingham)			788	Spring	
*Virginia Public Service Co., Grottoes, Va. (Rockingham)				S. F., Shenandoah	
Harrisonburg, Va. (Rockingham)			10,810	Subterranean dam on Dry R. basin	
*Harrisonburg Hydro-electric Plant, Va. (Rockingham)				S. F., Shenandoah	

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treatment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treatment	Receiving Stream
				9,800				S.F., Shenandoah
								S.F., Shenandoah
								S.F., Shenandoah
2,000		SF			15,000		Pri., E	Lewis Cr. of S.F., Shenandoah
144		CF						
					1,500		Pri., Sec., E	Christians Cr. of S.F., Shenandoah
					4,500		Pri., E	Christians Cr. of S.F., Shenandoah
					250		Pri., Sec., E	Trib. of South R. of S.F., Shenandoah
					150		Pri., Sec.	South R. of S.F., Shenandoah
					1,500		Pri., E	Middle R. of S.F., Shenandoah
				110			None	S.F., Shenandoah
	Hydro-electric plant (163 HP)							
140		D		135			None	S.F., Shenandoah
	Hydro-electric plant (420 HP)							
					10,000		Pri.	Blacks Run of S.F., Shenandoah
	Hydro-electric plant							

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Shenandoah River, W. Va.	171				
South Fork (continued)		55			
South River Sanitary District, Va. (Augusta)				Coles Run and Kennedy Run	3,500
Elkton, Va. (Rockingham)		55,84	1,361	Spring	
Merck & Co.					
Shenandoah, Va. (Page)			1,903	S. F., Shenandoah	2,000
Potomac Edison Co.				S. F., Shenandoah	
Norfolk & Western Railroad				S. F., Shenandoah	
*Massanutten Power Corp.				S. F., Shenandoah	
Stanley, Va. (Page)			399		
Potomac Edison Co.				S. F., Shenandoah	
Luray, Va. (Page)		55,49	2,731	Stoney Man Cr., Mary Rock Cr., Springs	
Potomac Edison Co.				S. F., Shenandoah	
*Page Power Co.				S. F., Shenandoah	
Stauffer Chemical Co., Bentonville, Va. (Warren)					
Front Royal, Va. (Warren)		55,4	8,115	S. F., Shenandoah	9,000
Viscose City					
American Viscose Corp.				S. F., Shenandoah	

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^-3)	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^-3)	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
		D						
				200			None	S.F., Shenandoah
					710		Pri., E	S.F., Shenandoah
							None	S.F., Shenandoah
	Hydro-electric plant (862 KW)	None						
1,000		FD						
	Hydro-electric plant (1,470 HP)							
							None	Trib. of S.F., Shenandoah
	Hydro-electric plant (1,400 KW)	None						
273					3,350		Pri., E	S.F., Shenandoah
	Hydro-electric plant (1,600 KW)	None						
	Hydro-electric plant (2,550 HP)							
					45		Pri., Sec.	S.F., Shenandoah
861		CF			8,500		Pri., E	Happy Cr. of S.F., Shenandoah
					400		Pri., Sec., E	S.F., Shenandoah
	In-dustrial	CF			2,200		Pri., Sec., E	S.F., Shenandoah

POTOMAC RIVER BASIN STUDIES

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Shenandoah River, W. Va.	171				
South Fork		55			
Front Royal, Va. (Warren) (continued)					
Beef Cattle Research				Springs and wells	
*Warren Power Co.				S. F., Shenandoah	
Potomac Edison Co., Riverton, Va. (Warren)				Shenandoah R.	
Northern Virginia Power Co., Riverton, Va. (Warren)				Shenandoah R.	30
Potomac Edison Co. Cedarville, Va. (Warren)				Shenandoah R.	
Berryville, Va. (Clark)			1,401	Mountain watershed	
Charles Town, W. Va. (Jefferson)			3,035	Springs	4,500
Halltown, W. Va. (Jefferson)		4	300		
Valley Paper Board Co.			160	Springs	
*Northern Virginia Power Co., Millville, W. Va. (Jefferson)				Shenandoah R.	
Michigan Limestone Division, U.S. Steel, Millville, W. Va. (Jefferson)				Shenandoah R.	
Blair Limestone Division, Millville, W. Va. (Jefferson)				Springs	
Potomac Edison Co., Millville, W. Va. (Jefferson)				Shenandoah R.	
Potomac Edison Co., Millville, W. Va. (Jefferson)				Shenandoah R.	

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treatment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treatment	Receiving Stream
					50		Pri., Sec.	Happy Cr. of S.F., Shenandoah
	Hydro-electric plant (1,200 HP)							
43,200	Power station cooling water (34,500 KW)							
		CF			25		Pri., E	Shenandoah R.
	Hydro-electric plant (750 KW)							
					1,500			Town Run Cr. of Shenandoah R.
450		D			1,500	900	ShCi Bo	Evitts Run of Shenandoah R.
								Shenandoah R.
2,225	Paper boxboard	Skp		2,225			S,11	Flowing springs of Shenandoah R.
	Hydro-electric plant (1,840 HP)							
	(cooling water)							
1,585	Sand washing	None	Inorganic	Pond seepage			L	Shenandoah R.
2,160	Sand washing	None	Inorganic	None			Lc	
21,600	Power station cooling water (8,700 KW)	None						
	Hydro-electric plant (2,840 KW)	None						

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Monocacy River, Md.	153				
Gettysburg, Pa. (Adams)			7,046	Well and Marsh Cr. of Monocacy R.	8,500
Littlestown, Pa. (Adams)			2,850	Springs and wells	3,000
Fairfield, Pa. (Adams)			451	Maple Spring Run of Monocacy R.	428
Camp Ritchey Project, U.S. Army, Pa. (Adams)					
Funkhouser Co., Pa. (Adams)			76	Miney Br. of Toms Cr. of Monocacy R.	
Knouse Food Corp., Ortana, Pa. (Adams)			200 (at peak)	Wells and Marsh Cr. of Monocacy R.	
B. H. Shriver Co., Pa. (Adams)			84	Piney Cr. of Monocacy R.	
A. W. Feeser Co., Inc., Silver Run, Md. (Carroll)					
Taneytown, Md. (Carroll)			1,420	Wells	1,800
Cambridge Rubber Co.					
Essig Packing Co.					
E. J. Nusbaum Co.			40		
A. W. Feeser Co., Inc.					
Westminster, Md. (Carroll)			6,140	Hull Cr. and Cranberry Br. of N. Br. Patapsco R.	

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
560		CalMb FrFzDc		500	7,500	480	GhSc CmFt2h CmEgc DchrBc	Rock Cr. of Monocacy R.
150		Dhc		140	2,850		ShCm FtlhCm EcgDf hrToBo	Fox Cr. of Monocacy R.
10		Dh					On lot disposal	
				220	1,100 to 2,200		ShCi FtnCp EcgBo	Miney Br. of Toms Cr. of Monocacy R.
108			Silt				Silt La-goons	Miney Br. of Toms Cr. of Monocacy R.
100								No discharge
83								No discharge
			Vege-table canning	35			SfL, 10	Pipe Cr. of Monocacy R.
200		Dh		200	1,800		ScCi Ftrh Cm EgcBo	Piney Cr. of Monocacy R.
			Oil, cool-ing water, septic tank eff., boiler	48			CO	Piney Cr. of Monocacy R.
			Chicken killing: feathers, blood, solids	12			11, SCs	Piney Cr. of Monocacy R.
			Vegetable canning, cooling. water	50			Sf	Piney Cr. of Monocacy R.
			Vegetable canning	35			SfL, 10	Piney Cr. of Monocacy R.
		FKNDc			4,692	630	ShCm Ftr CmDm crBo	Little Pipe Cr. of Monocacy R.

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Monocacy River, Md.	153				
Westminster, Md. (Carroll) (continued)					
Mount Pleasant Canning Co.					
Willow Farm Dairy					
Western Maryland Dairy, New Windsor, Md. (Carroll)					
New Windsor Farmers' Cooperative, New Windsor, Md. (Carroll)					
Joseph H. Weller Co., Linwood, Md. (Carroll)					
Yingling Brothers Co., Union Bridge, Md. (Carroll)					
A. W. Feeser Co., Inc., Keymar, Md. (Carroll)			40		
George W. Magin Co., Taylorsville, Md. (Carroll)					
Western Maryland Dairy, Detour, Md. (Carroll)			25		
*Maryland TB Sanitorium, Md. (Frederick)				Wells and spring; Owens Cr. of Monocacy R.	
Emmitsburg, Md. (Frederick)			1,300	Turkey Br. and springs	1,300
St. Mary's College			600		
*St. Joseph's Academy					
Thurmont, Md. (Frederick)			1,676	High Run, wells, springs	2,500
Thurmont Rendering Co.					
Howard Lotte & Co.			10		
Fraley's Meats, Catoctin Furnace, Md. (Frederick)					

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10-3)	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10-3)	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
			Vegetable canning	30			CSf	Monocacy R.
			Milk process wash water	40			11	Meadow Br. of Monocacy R.
			Milk process wash water	30		23	11	Little Pipe Cr. of Monocacy R.
			Cooling water	15			None	Little Pipe Cr. of Monocacy R.
			Vegetable canning	15			11	Little Pipe Cr. of Monocacy R.
			Slaughter house	10			S,11	Little Pipe Cr. of Monocacy R.
			Vegetable canning	60		3,000	SfL	Pipe Cr. of Monocacy R.
			Cooling water	20			0	Talbot Br. of Monocacy R.
			Milk process wash water	125		625	11,Cs	Double Pipe Cr. of Monocacy R.
88				88	600			Owens Cr. of Monocacy R.
200		Dc			1,050	700	Slo ClEgc Bo	Flat Run of Monocacy R.
					600	400	ShOCl EgBo	Trib. of Toms Cr. of Monocacy R.
				100	400			Monocacy R.
500		Dh		500	2,500		ShKCm FtCm EgcDo mp	Hunting Cr. of Monocacy R.
			Animal rendering				CaIs	Little Hunting Cr. of Monocacy R.
			Slaughter house			2,000	11,S Muni-cipal sewer	Big Hunting Cr. of Monocacy R.
			Slaughter house	Variable		1,000	Sf,11	Little Hunting Cr. of Monocacy R.

POTOMAC RIVER BASIN STUDIES

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Monocacy River, Md. (continued)	153				
Castle Cheese Co., Sixs Bridge, Md. (Frederick)					
Walkersville, Md. (Frederick)		24	761	Wells, springs, stream	
Western Maryland Dairy, Unionville, Md. (Frederick)					
Frederick, Md. (Frederick)		19	18,142	Fishing Cr. and Tuscarora Cr; Linganore Cr., all of Monocacy R.	19,990
Everedy Co.			225	Frederick, Md.	
Camp Dietrick, U. S. Army				Monocacy R.; Frederick, Md.	
Headquarters, Camp Dietrick, U. S. Army (Experimental Station)					
Eberts Ice Cream					
Tydol Service Station					
Alpha Portland Cement Co., Lime Kiln, Md. (Frederick)				Monocacy R.	
Hardy and Green Co., Kemptown, Md. (Montgomery)					
Mount Airy Motors, Mount Airy, Md. (Frederick)					
Western Maryland Dairy, Mount Airy, Md. (Frederick)					
George McComas & Co., Monrovia, Md. (Frederick)					

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
			Cottage cheese & butter process	8 (once a week)		369	CsI	Monocacy R.
		Dh						Monocacy R.
			Milk process wash water	36		180	11	N.F. of Lingamore Cr.of Monocacy R.
2,800		DcNV		2,800	19,000	24,000	ScCm Ftlh CmEg HoVvXn	Monocacy R.
150	Plating		Chrome	150			11	Carroll Cr. of Monocacy R.
		FIDc					ShCm Ftr CpEgDo pmBo	Monocacy R.
			Cooling water				0	Carroll Cr. of Monocacy R.
			Ice cream process wash water	Variable for 3-hr. discharge per day			Cs	Unnamed small springhead of Monocacy R.
			Auto service station				11	Carroll Cr. of Monocacy R.
432								
			Wormseed oil and cooling water	30			2,L	Fahrney Br. of Monocacy R.
			Auto service station				11	Woodville Br. of Lingamore Cr. of Monocacy R.
			Milk process wash water	11			11	Little Lingamore Cr. of Monocacy R.
			Corn canning	24			Sf,I	Bush Cr. of Monocacy R.

POTOMAC RIVER BASIN STUDIES

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Goose Creek, Va.	142				
Middleburg, Va. (Loudoun)			663	Surface	
Middleburg Training Center					
Purcellville, Va. (Loudoun)			945	Surface	
Leesburg, Va. (Loudoun)			1,703	Spring and well	
*Virginia Public Service Co.				Goose Creek	
Leesburg Motel					
Goose Cr. Country Club Swimming Pool, Va. (Loudoun)					
Foxcroft School, Va. (Loudoun)				Wells	
Muddy Branch, Md.	132				
Washington Suburban Sanitary District, Gaithersburg, Md., (Montgomery)					
Cabin John Creek, Md.	118				
Rockville, Md. (Montgomery)			17,000		
Anacostia River	108				
Contee Sand & Gravel Co., Laurel, Md. (Prince Georges)					
Prince Georges Sand and Gravel Co., Contee, Md. (Prince Georges)					
Mineral Pigment Corp., Muirkirk. Md. (Prince Georges)					

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
					500		Pri., Sec.,E	Wagwipin Run
					200		Pri., Sec.,E	Goose Cr.
					*20		Pri., Sec.	Goose Cr.
					800		Pri., Sec.,E	Goose Cr.
					2,000		Pri., Sec.,E	Tuscarara Cr. of Goose Cr.
	Hydro-electric plant (800 HP)							
							Pri., Sec.,E	Tuscarara Cr. of Goose Cr.
					*300		Pri., Sec.	Goose Cr.
					195		Pri., Sec.,E	Goose Cr.
					2,270		ShKCl FthCl HoBoLs	Muddy Br. of Potomac R.
							Wash. Suburban Sanitation District	
			Silt and clay	800			Set-tling ponds	Indian Cr. of Anacostia R.
			Silt and clay	500			Set-tling ponds	Little Paint Br of Anacostia R.
			Inorganic pigments	20			CXm	Indian Cr. of Anacostia R.

POTOMAC RIVER BASIN STUDIES

Name and Location of Industry or Municipality	Miles from Mouth		Population or Employees	WATER	
	Potomac	Tributary		Source of Supply	Population Served
Potomac River					
Anacostia River (continued)	108				
National Agricultural Research Center, Beltsville, Md. (Prince Georges)			650		
U. S. Horticultural Station, Beltsville, Md. (Prince Georges)			450		
Greenbelt, Md. (Prince Georges)			7,074		
A. H. Smith Sand & Gravel Co., Branchville, Md. (Prince Georges)					
Uno Excavating Co., Berwyn, Md. (Prince Georges)					
McCeney Sand & Gravel Co., White Oak, Md. (Prince Georges)			30		
Washington Suburban Sanit. District, D.C.				Northwest Br. of Anacostia R.; Patuxent R.	500,000
Howart Concrete Co., D.C.			35		
Smoot Sand and Gravel Plt, S.W., D.C.			8		
Washington Gas and Light Co., D.C.					
Potomac Edison Power Co., Benning Station, D.C.				Anacostia R.	
Occoquan Creek, Va.	84				
Manassas, Va. (Prince William)			1,804	Wells	
*Bull Run Power Co.				Bull Run of Occoquan Cr.	
Manassas Park Subdivision					

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^-3)	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^-3)	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
					650	130	ShEg KmCp FtrCp EgDfr Bc	Beaverdam Cr. of Anacostia R.
					450	90	ShCi Ftr CpEg Bo	Little Paint Br. of Anacostia R.
					4,000		ShOa CmFtr CmDcp BcLs	Beaverdam Cr. of Anacostia R.
			Silt and clay	4,050			CL	Indian Cr. of Anacostia R.
			Silt and clay	300			L	Indian Cr. of Anacostia R.
			Silt and clay				Set-tling pond	Northwest Br. of Anacostia R.
		FKDcV		7,500	81,000		Blue Plains Wash. D.C.	
			Inorganic				C	Anacostia R.
			Inorganic				None	Anacostia R.
			Gas plant				CF	Anacostia R.
180,000			Power plant cooling water					
180		D			1,775		Pri., Sec., E	Flat Run of Bull Run of Occoquan Cr.
	Hydro-electric plant (272 HP)							
					4,800		Pri., Sec., E	Bull Run of Occoquan Cr.

Name and Location of Industry or Municipality	Miles from Mouth Potomac	Miles from Mouth Tributary	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River					
Occoquan Creek, Va. (continued)	84				
Quantico Marine Base, Camp Goettge, Va. (Prince William)					
Vint Hill, Va. (Fauquier)				Well	1,900
Vienna, Va. (Fairfax)			2,029	Wells	
D.C. Work House, Lorton, Va., (Fairfax)					
Occoquan, Va. (Prince William)			213		
Chopawamsic Creek	79				

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
					750		Pri., Sec., E	Trib. of Bull Run of Occoquan Cr.
190					600		Pri., Sec.,E	South Run of Occoquan Cr.
					1,300		Pri., Sec.,E	South Run of Occoquan Cr.
203					2,000		Pri., Sec.,E	Difficult Run of Occoquan Cr.
					1,200		Pri., Sec.,E	Occoquan Cr.
							None	Occoquan Cr.

POTOMAC RIVER BASIN STUDIES

Name and Location of Industry or Municipality	Miles from Mouth of Potomac	Population or Employees	WATER Source of Supply	Population Served
Potomac Rivir				
Paw Paw, W. Va. (Morgan)	277	820	Drilled well	834
Hancock, Md. (Washington)	239	963	Potomac R. and Little Tonoloway Cr.	1,000
Williamsport, Md. (Washington)	211	1,890	Hagerstown, Md.	
Potomac Edison Co.	210		Potomac R.	
Meare Sand and Gravel Co., Shepherdstown, Md. (Washington)				
*Potomac Light and Power Co., Hedgesville, W. Va. (Berkeley)			Potomac R.	
Potomac Edison Co., Falling Waters, W. Va. (Berkeley)			Potomac R.	
supont, Falling Waters, W. Va., (Berkeley)			Potomac R.	
Shepherdstown, W. Va. (Jefferson)	183	1,173	Potomac R.	2,000
Potomac Edison Co.			Potomac R.	
*Potomac Light and Power Co.			Potomac R.	
Harpers Ferry, W. Va. (Jefferson)	171	822	Spring and surface	2,000
Potomac Edison Co.			Potomac R.	
*Harpers Ferry Electric Light and Power Co.			Potomac R.	

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10-3)	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10-3)	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
45		ISFpD			800		ShCi EcgBo	Potomac River
400		FrKDc			780		None	Potomac River
130		DcMKV		*30 *5 *65		200 400 845	ShCi Cs ShCi	Conococheague Cr. Conococheague Cr. Potomac R.
172,800	Power plant cooling water (84,000 KW)	None	Fly ash, slag, cinders in wash water				Lp	Potomac R.
			Silt	288			Lp	Potomac R.
	Hydro-electric plant (1,120 HP)							
	Hydro-electric plant (1,120 KW)	None						
500	Cooling, explo-sives manuf.	CaSDc Fr	Cooling water, residual chemi-cals	500			11	Unnamed Trib. of Opequon Cr. and Potomac R.
90		CSDF		90	2,000		None	Potomac R.
	Hydro-electric plant (1,000 KW)	None						
	Hydro-electric plant (1,000 HP)							
76		D			250		None	Potomac R. and Shenandoah R.
	Hydro-electric plant (840 KW)	None						
	Hydro-electric plant (1,022 HP)							

POTOMAC RIVER BASIN STUDIES

Name and Location of Industry or Municipality	Miles from Mouth of Potomac	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River				
Brunswick, Md. (Frederick)		3,752	Springs	4,500
Baltimore and Ohio Railroad				
Rockville, Md. (Montgomery)			Wells and D.C. SSC	20,000
McCeney Sand and Gravel Co., White Oak, Md. (Montgomery)				
Naval Model Testing Station, Carderock, Md. (Montgomery)				1,200
Herndon, Va. (Fairfax)		1,461	Wells	
Hollin Hall Village, Va. (Fairfax)			Well	400
Great Falls Park, Va. (Fairfax)	127			
Madeira School, Va. (Fairfax)				
U.S. Bureau of Public Roads, Langley, Va. (Fairfax)				
Fairfax Sanitary District No. 1, Va. (Fairfax)				
Chesterfield Subdivision, Va. (Fairfax)				
Pimmit Hills, Va. (Fairfax)				
Churchill Subdivision, Va. (Fairfax)				
Washington, D.C.	115	802,178	Potomac R.	1,035,000
Corson and Gruman				25
Maloney Concrete Co.				40
Smoot Sand and Gravel Plt, N.W.				11
Smoot Sand and Gravel Plt, S.E.				7
Super Concrete Co.				40

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
500		D		500	3,600		SC1	Potomac R.
			Locomotive and parts wash water	<1			OO	Potomac R.
2,000		Dc & FKDcV			20,000		Pri., Sec.,E	Potomac R.
			Silt and clay	800			Lp	Paint Br. of Potomac R.
		C			1,200	800	ClEgc Bo	
146					1,100		Pri., Sec.,E	Sugarland R. of Potomac R.
20					400		Pri., Sec.,E	Little Hunting Cr. of Potomac R.
					3,000		None	Potomac R.
					200		Pri., Sec.,E	Trib. of Potomac R.
					700		Pri., Sec.	Potomac R.
					80,000		Pri., Sec.,E	Potomac R.
					800		Pri., Sec.,E	Pimmit Run of Potomac R.
					800		Pri., Sec.,E	Pimmit Run of Potomac R.
					600		Pri., Sec.,E	Pimmit Run of Potomac R.
		FDK			900,783		CmCa CmDc resZiVv	Potomac R.
			Nonmetallic minerals				None	Potomac R.
			Nonmetallic minerals				None	Potomac R.
			Nonmetallic minerals				None	Potomac R.
			Nonmetallic minerals				None	Potomac R.
			Nonmetallic minerals				None	Potomac R.

Name and Location of Industry or Municipality	Miles from Mouth of Potomac	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River				
Washington, D.C. (continued)	115			
Potomac Electric Power Co., Buzzard Point			Potomac R.	
Arlington County, Va. (Arlington)	108	157,236	Washington, D.C.	
Arlington Asphalt Co., Rosslyn, Va. (Arlington)				
Worthington Oil Refinery, Rosslyn, Va. (Arlington)				
Pentagon Building, Arlington, Va., (Arlington)				
Alexandria, Va. (Arlington)	105	33,523	Occoquan Cr. and wells	125,000
Virginia Public Service Co.			Potomac R.	
Braddock Light and Power Co.			Potomac R.	
Buffalo Sand and Gravel Co., Silver Hill, Md. (Prince Georges)				
Washington Sand and Gravel Co., Marlboro Pike, Md. (Prince Georges)				
Smoot Sand and Gravel Co., Potomac River, Md. (Prince Georges)				
Parr Warehouse, Franconia, Va., (Fairfax)				
Virginia Electric and Power Co., Possum Point, Va. (Fairfax)				
Mt. Vernon Estates, Va. (Fairfax)				
Fort Belvoir, U.S. Army, Va. (Fairfax)	94		Accotink Cr.	17,000

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Sewerage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
450,000 (Summer) 380,000 (Winter)	Power plant cooling water							
					197,236		Pri.	Four Mile Run of Potomac R.
							None	Potomac R.
							None	Potomac R.
					30,000		Pri., Sec.,E	Potomac R.
13,000		P-TcDc CalMhSv FrsDdCs KpVsTd			150,000		Pri., Sec.,E	Hunting Cr. of Potomac R.
7,500	Power plant cooling water	FD						
193,000	Power plant cooling water							
			Silt and [illegible]	800			Lp	Henson's Br. of Potomac R.
			Silt and clay				Lp	Oxon Run of Potomac R.
			Silt and clay	[illegible]			None, or barged to approved area	Potomac R.
					530		Pri., Sec.,E	Trib. of Potomac R.
							Pri., Sec.	Potomac R.
					400		Pri.	Potomac R.
1,000		FC					Pri., Sec.,E	Potomac R.
					17,000		Pri.,E	Potomac R.

POTOMAC RIVER BASIN STUDIES

Name and Location of Industry or Municipality	Miles from Mouth of Potomac	Population or Employees	WATER Source of Supply	WATER Population Served
Potomac River				
Yacht Haven Estates, Va. (Fairfax)				
Fairfax, Va. (Fairfax)		1,946	Wells	
Glymont, Md. (Charles)	89	150		
Indian Head Power Plant, Md. (Charles)			Potomac R.	
Brown Field, Camp Goettge, Va., (Prince William)				
Linton Hall, Va. (Prince William)				
Occoquan-Woodbridge Sanitary District, Muruneco Sewage Treatment Plant, Va., (Prince William)				
Garfield Estates, Va. (Prince William)				
Dahlgreen Elementary School, Va., (Prince William)				
Dumfries School, Va. (Prince William)				
Melrose Gardens, Va. (Prince William)			Wells	1,480
Quantico Marine Base, Midway Island, Va. (Prince William)	79		Potomac R.; wells	
Camp Upshar, Va. (Prince William)				
Camp Barrett, Va. (Prince William)				
Triangle Sanitary District, Va. (Prince William)				
Lynwood Subdivision, Va. (Prince William)				
*Colonial Beach, Va. (Westmoreland)	37.5	1,105		

SUPPLY			WASTE DISCHARGE					
Quantity Used gpd(10^{-3})	Use of Water	Treat-ment	Type Waste	Quantity Discharged gpd(10^{-3})	Population Served (Severage)	Pop. Equiv. BOD Discharged	Treat-ment	Receiving Stream
					150		Pri.,E	Dogue Cr. of Potomac R.
195					5,000		Pri., Sec.,E	Accotink Cr. of Potomac R.
					1,800		ShCm Egc DfrBo	Potomac R.
12,960	Power plant cooling water	D						
					1,500		Pri.	Potomac R.
					750		Pri., Sec.E	Trib. of Bull Run
					300		Pri.,E	Broad Run of Potomac R.
					3,000		Pri., Sec.,E	Marumsco Cr. of Potomac R.
					600		Pri., Sec.,E	Neabsco Cr. of Potomac R.
					400		Pri., Sec.	Potomac R.
					700		Pri., Sec.	Trib. of Quantico Cr. of Potomac R.
12					2,500		Pri., Sec.,E	Quantico Cr. of Potomac R.
3,500		FC;C			20,000		Pri., Sec.	Potomac R.
					1,100		Pri., Sec.,E	Chopawamsic Cr.
					2,000		Pri., Sec.,E	Trib. of Potomac R.
					2,000		Pri., Sec.,E	Trib. of Potomac R.
					1,000		Pri., Sec.,E	Trib. of Potomac R.
					400		Pri., Sec.	Marumsco Cr. of Potomac R.
				50			GCDHE (Under constr.)	Potomac R.

PART III

INVESTIGATION OF WATER USES, POLLUTION SOURCES, AND WATER QUALITY IN THE UPPER POTOMAC RIVER BASIN

ACKNOWLEDGMENTS

To develop a report of this kind requires considerable assistance and cooperation from many factions located in or having jurisdiction over matters relative to the study region.

The utmost cooperation in supplying necessary information was extended by interstate, state, municipal, and industrial agencies and authorities in Maryland, Pennsylvania, Virginia, West Virginia, and District of Columbia.

Regional information and hydrological data were provided through the cooperation of the U. S. Geological Survey and the Corps of Engineers, U. S. Army.

Special acknowledgment is made for the assistance given by the City of Hagerstown, Maryland, in providing space and facilities for operation of the mobile laboratory during the 1958 field survey.

INTRODUCTION

This report presents the results of an investigation of water uses, pollution sources, and stream water quality in the Potomac River Basin. The study was made at the request of the Corps of Engineers, Washington District, to aid in the development of a comprehensive water resources plan for the Potomac River Basin. It supplements, in part, a report prepared by the Public Health Service in 1957 on the North Branch of the Potomac River.

Authority for the investigation was granted by the Corps of Engineers in a letter dated June 6, 1958, accepting and approving the plan of study as previously outlined by the Public Health Service in correspondence dated December 3, 1957.

The scope of the study includes the following: compilation of water uses and sources; identification of pollution sources; investigation of the effects of waste on the receiving streams; presentation of water quality objectives for streams affected by wastes; recommendations for special stream and waste surveys where needed (in collaboration with appropriate state agencies) to supplement existing information in identifying characteristics; and evaluations of stream water quality relative to water supply and sanitation objectives.

The portion of the basin covered in the report is that lying above Great Falls, or that which is identified as the Upper Potomac River Basin.

Details on municipal and industrial water supplies and waste disposal practices are given for the entire area, whereas water quality data are necessarily confined to major streams and stream sections.

Discussions are designed primarily to aid in the establishment of reservoir sites, since they involve water supply and sanitation objectives relative to various stream sections and possible reservoir sites.

The data on water uses and waste sources were supplied by state, interstate, and local agencies and authorities in the region. Only few recent stream quality data, however, were available. With the exception of recent water quality data supplied by the City of Hagerstown and the Water Division of the District of Columbia, most of the water quality data shown are those collected during the Public Health Service field survey of September and October 1958.

SUMMARY

1. According to the compilation of data obtained from state and local authorities, approximately 412,000 persons are served by municipal or privately owned water supplies in the Upper Potomac Basin.[1]

2. Water used for domestic purposes in the basin amounts to approximately 56.5 mgd, or a per capita use of 137 gpd.

3. Eighty per cent of the water used for domestic purposes is obtained from surface water sources.

4. The use of water for industrial processing in the Potomac Basin is about 150 mgd.[2]

5. Ninety per cent of the water used for industrial processing is obtained from surface sources.

6. Water use for industrial cooling purposes in the Potomac Basin is approximately 390 mgd.

7. Electrical energy produced by hydroelectric power plants in the Potomac Basin is about 15,000 HP.

8. Fishing and water sports are important recreational activities in various parts of the basin. Moderate use of the Potomac River for fishing was observed from Hancock, Maryland, downstream to Point of Rocks. The South Branch and Cacapon Rivers are reported to be extremely popular fishing streams. The Potomac River at Shepherdstown is used for boating and swimming, and reports indicate a growing use of the river near Falling Waters for all types of water sports.

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[1]All references to domestic water and waste pertain to the entire area above Great Falls.

[2]All references to industrial water and wastes include the North Branch Potomac and Virginia portion of the Shenandoah River.

9. Approximately 350,000 persons or 85 per cent of the urban population in the basin are served by sewage collection facilities.

10. Potomac Basin streams receive treated and untreated domestic sewage equivalent to the biochemical oxygen demand (BOD) of raw sewage from approximately 210,000 persons.

11. The average reduction in domestic sewage BOD attributable to waste treatment in the Potomac Basin is about 40 per cent.

12. Industrial wastes received by Potomac Basin streams are equivalent to sewage from a population of about 518,000 persons.

13. Industrial activities in the Potomac Basin producing organic polluting substances are: pulp and paper, synthetics, textile, tanning, pharmaceutical, poultry processing, canning, dairy products, and slaughtering.

14. Industrial activities producing inorganic wastes substances are: pulp and paper, tanning, textile, chemical, pharmaceutical, metal plating, aircraft manufacturing, explosives manufacturing, synthetics, plate glass, glass-sand, cement, sand and gravel, limestone, coal mining, and electric power.

15. Water of unsatisfactory quality for water supply purposes was found downstream from sewage and industrial waste discharges to the following major streams: South Branch Potomac, Conococheague Creek, Opequon Creek, Antietam Creek, Monocacy River, and Shenandoah River.[1]

16. Warm Springs Run was grossly polluted by glass-sand waste which, upon discharge to the Potomac River, adversely affected the water quality and aquatic environment of the Potomac River for many miles downstream.

17. Pollution of domestic origin was indicated at the lower extremities of the following minor tributaries: Patterson Creek, Little Tonoloway Creek, and Catoctin Creek.

18. Tributary streams of suitable quality in their entirety for water supply purposes are: North Fork of South Branch Potomac, Town Creek, Little Cacapon Creek, Cacapon River, Sleepy Creek, Licking Creek, and Back Creek.

19. Most Potomac Basin streams possess excellent waste assimilative capacities by virtue of riffle and shallow pool characteristics.

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[1]All statements relative to water quality do not include the North Branch Potomac or Virginia portion of the Shenandoah River.

20. The main stem of the Potomac River contained concentrations of phenolic compounds (as tannin) in excess of recommended limits for tastes and odors in drinking water.

21. The turbidity of Potomac River water varies directly with the rate of stream discharge. Turbidities of stream water at the Hagerstown Water Treatment Plant can vary from 2 to 800 units depending upon the stage of the river.

22. The West Virginia section of the Shenandoah River contained dissolved iron and manganese in excess of the recommended maximum concentrations for these materials in drinking water.

23. The Potomac River at Great Falls contained considerably more biochemical oxygen demand than could be accounted for from nearby upstream waste sources. The indicated delay in BOD satisfaction is characteristic of effects associated with the presence of biochemical retarding substances.

24. The average 5-day and corresponding ultimate BOD of Potomac River water at Great Falls was 28,000 and 46,500 pounds per day, respectively.

25. According to stream BOD data, fourteen stream sections contained excessive organic waste loads. These stream sections are as follows:

(1) South Fork South Branch Potomac below Moorefield, W. Va.
(2) Potomac River below confluence of North and South Branches.
(3) Little Tonoloway Creek at Hancock, Md.
(4) Warm Springs Run below Berkeley Springs, W. Va.
(5) Conococheague Creek below Chambersburg and Mercersburg, Pa.
(6) Potomac River between Williamsport, Md. and mouth of Antietam Creek.
(7) Opequon Creek below Martinsburg, W. Va.
(8) Antietam Creek below Hagerstown, Md.
(9) Shenandoah River from West Virginia State Line to mouth.
(10) Potomac River at Point of Rocks.
(11) Rock Creek of Monocacy River below Gettysburg, Pa.
(12) Monocacy River below mouth of Double Pipe Creek.
(13) Monocacy River below Frederick, Md.
(14) Potomac River between mouth of Shenandoah River and Great Falls.

26. Good quality water and relatively insignificant sources of pollution exist in the vicinity of four possible dam sites on Patterson Creek of the North Branch Potomac. Community relocations, where applicable, should include provisions for sewage collection and treatment or a means of preventing wastes from entering the reservoirs.

27. The possible reservoir sites on the North and South Forks of the South Branch Potomac would provide excellent sources of water for downstream uses.

28. Water of good quality exists in the vicinity of three possible dam sites on the main stem of the South Branch Potomac above Petersburg, W. Va. The site immediately below Franklin, W. Va., would be subject to sewage contamination requiring considerations for recreational restrictions or complete treatment of sewage with chlorination at Franklin to reduce the health hazard in headwater areas of the reservoir.

29. The possible reservoir site on the South Branch Potomac below Romney, W. Va., is subject to residual municipal and industrial wastes affecting potable and sanitary quality. Appropriate restrictions and/or treatment of water or wastes should be considered.

30. Although no water quality data are available relative to possible reservoir sites on Town Creek, Little Cacapon Creek, and Sideling Hill Creek, the absence of significant population centers or potential sources of pollution makes it appear that these waters would be suitable as a source of water supply.

31. The possible dam sites on the Lost River, North River, and main stem of the Cacapon River are in areas of good quality water. Recreational restrictions or complete treatment of sewage with effluent chlorination at the Lost River State Park should be considered for the Lost River site, and the community relocations relative to these sites should include provisions for waste treatment or elimination of waste disposal to the reservoirs.

32. Although no water quality data are available relative to possible reservoir sites on Tonoloway Creek and Licking Creek the absence of significant population centers or potential pollution sources makes it appear that these waters would be suitable as a source of water supply.

33. The possible reservoir site on Sleepy Creek would provide a suitable source of supply, since good quality water exists in the region and no significant centers of population or potential sources of pollution exist upstream.

34. Water of good quality exists in the vicinity of the possible site on Back Creek. Potential sources of pollution exist upstream, however, necessitating considerations for appropriate recreational restrictions of the reservoir or means of reducing pollution by waste treatment at the sources.

35. The possible reservoir site on the West Branch of Conococheague Creek would provide a suitable source of water supply and offer substantial local pollution abatement benefits by low flow augmentation at points downstream.

36. The possible reservoir site on the main stem of Conococheague Creek is subject to municipal and industrial wastes affecting potable and sanitary quality. Appropriate restrictions and/or treatment of water or wastes should be considered. Substantial local pollution abatement benefits by low flow augmentation could accrue at points downstream.

37. The waters upstream from the possible dam site on Opequon Creek contain excessive sewage bacteria and relatively high concentrations of mineral salts. Appropriate restrictions for health protection and/or treatment of water and wastes should be considered. The site would provide downstream benefits provided the stored water is of suitable quality.

38. All water storage facilities in the Potomac Basin designed to provide significant flow increases at municipal and industrial water intakes and waste discharge points during drought periods would improve the general health and future economic well being of the populations residing in the Upper Potomac Basin. The facilities would also be especially beneficial in satisfying water supply demands and pollution abatement needs in the Washington Metropolitan Area.

RECOMMENDATIONS

1. Because most of the major Potomac Basin streams contain coliform group organisms in excess of maximum numbers recommended for water supplies requiring complete treatment, it is recommended that the sources be accurately identified and that corrective action be taken by local authorities to reduce these numbers where deemed necessary.

2. An extensive water quality survey should be conducted in the Shenandoah Basin to define stream water quality and waste characteristics.

3. An investigation of possible types, sources, and effects of toxic waste substances should be made at various strategic locations in the Potomac Basin above Great Falls.

DESCRIPTION OF THE REGION

GEOGRAPHY

From its headwaters on the eastern slopes of the Appalachian Mountains, the Potomac flows in a general southeasterly direction some 400 miles to Chesapeake Bay. The main stem is formed approximately 20 miles below Cumberland, Maryland, at the confluence of the North and South Branches of the Potomac and flows southeast to the Fall Line at Great Falls, Virginia. About ten miles below the Falls, at Chain Bridge, the lower river, or tidal section, is formed.

The portion of the Potomac River above the Fall Line--that concerned in this investigation--is about 266 miles long, and follows a course through the mountainous terrain of the Alleghenies, across the fertile Shenandoah Valley, through the Blue Ridge Mountains, and across the rolling hills of the Piedmont Plateau to the Fall Line and the Coastal Plain. It drains an area of about 11,500 square miles in Maryland, Pennsylvania, West Virginia, and Virginia. It is a comparatively narrow fast-flowing stream flanked by steep banks and mountains, and has many natural obstructions and rapids.

The Potomac tributaries possess essentially the same features as the main stem above the Fall Line. The Shenandoah River is the largest tributary stream. It flows along the western base of the Blue Ridge Mountains, draining the wide valley to which it has given its name, and enters the Potomac at Harpers Ferry, West Virginia. Other principal tributaries are the Cacapon, the Monocacy, the North Branch, the South Branch, and Conococheague and Antietam Creeks. Below Harpers Ferry tributaries bring in large quantities of sediment, causing high turbidity in the main stream.

The average recorded discharge at Washington, D. C. is 11,340 cubic feet per second. Discharges of 484,000 cubic feet per second and less than 800 cubic feet per second have been recorded. The shape and character of the basin are such that they favor rapid runoff, with high discharges occurring for short periods of time and low flows existing for sustained periods during drought seasons. The Potomac River and tributaries thus are characterized by flash floods and extremely low flows.

ECONOMICS

The populations in the Potomac River Basin above Great Falls are located primarily on farms and in numerous small towns. The largest community in the region is Hagerstown, Maryland, with a population according to 1950 census of 36,260. There are several towns with populations of 10,000 - 20,000 and numerous smaller communities. A large proportion of the population is rural.

Farming and related industries such as canning, fruit packing, tanning, and dairy products processing, are a major source of income to the region. There are some large industries located throughout the basin, mainly in the vicinities of Hagerstown and Frederick, Maryland; Chambersburg, Mercersburg, Gettysburg, and Waynesboro, Pennsylvania; Harrisonburg, Staunton, Waynesboro, Luray, Front Royal, and Winchester, Virginia; and Martinsburg, West Virginia. These industries include manufacturers of textiles, rubber, paper products, hosiery, and chemicals in addition to the related agricultural industries already listed.

Parts of the basin are considered to be among the nation's most popular recreational areas. There are many historic and scenic attractions, some of which are the Skyline Drive, limestone caverns, the Great Falls of the Potomac, and several Civil War battlefields.

The Upper Potomac River Basin has abundant natural resources consisting of limestone, dolomite, glass sand, clay, hard and soft woods, and granite. Many of these resources are largely untouched and offer potentialities for large industrial development.

STUDY PROCEDURES

PRELIMINARY INVESTIGATION

Initial contacts were made with appropriate state and interstate agencies for the purpose of obtaining available information on the water supplies and waste disposal practices in the regions being studied. Public Health Service personnel visited and received data from the following agencies:

Maryland Department of Health
Maryland Water Pollution Control Commission
Pennsylvania Department of Health
Virginia State Department of Health
Virginia State Water Control Board
West Virginia State Water Commission
Interstate Commission on the Potomac River Basin

In general, only a few stream data were available. The State of Virginia had made an extensive stream survey of the South River in the vicinity of Waynesboro, Virginia, in the Summer of 1957. No recent surveys had been conducted in the Maryland and West Virginia regions. Pennsylvania had undertaken a stream survey of Conococheague Creek in 1951, and a co-operative study was made by Maryland, West Virginia, and the Public Health Service in 1953 on the effects of glass plant waste on the Potomac River between Hancock, Maryland, and Williamsport, Maryland.

ASSEMBLY OF PRELIMINARY DATA

The data on water supplies and waste disposal practices provided by state and interstate agencies were compiled and submitted in the Potomac River Basin Study, Preliminary Compilation of Data on Water Uses in the Potomac River Basin, May 1958.

FIELD INVESTIGATIONS

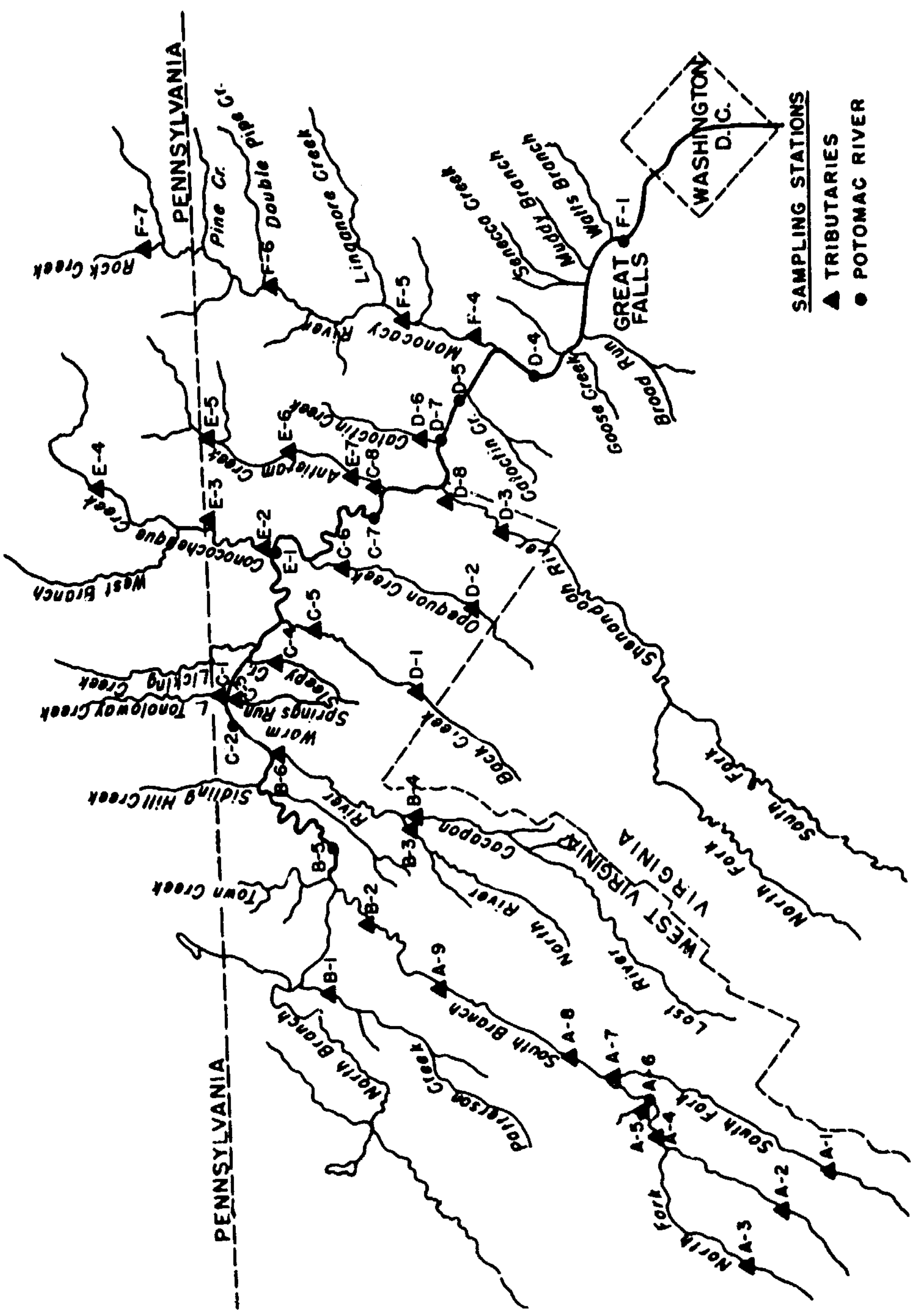
Upon examination of all preliminary data it was determined that a detailed field survey of the Upper Potomac River Basin was required. The survey program was outlined to develop the following required information:

(1) Obtain additional information on water supplies and waste sources;
(2) Determine the water quality of major streams in the basin;
(3) Determine local effects of specific wastes.

Authority to conduct the field survey was granted by the Corps of Engineers in a letter dated August 26, 1958. The survey, consisting of six weeks of study, was made during September and October of 1958 when relatively low stream flows prevailed at which time the critical conditions of the streams could be studied. Information relative to water uses and waste sources was obtained by direct contacts with municipal and industrial representatives concurrently with the water quality sampling program. As a result of these contacts a revised tabulation of data on water uses was prepared and submitted as Part II, Report of the Potomac River Basin Study, November 1958.

The water sampling program involved forty-two sampling stations in the States of Maryland, Pennsylvania, and West Virginia. The area was divided into six sections in order that each could be sampled and the samples returned to the mobile laboratory at Williamsport, Maryland, within a period of six to eight hours. Each section was sampled once a week for the six week period with the exception that the main stem Potomac River sampling stations were sampled seven times and one tributary containing extremely variable waste discharges was sampled thirteen times. For identification purposes each section was assigned a letter of the alphabet from (A) through (F) followed by numbers identifying the sampling stations within each section. The sampling station locations with identification letters and numbers are shown in Figure 1 and the corresponding descriptions of the locations are given in Table 4.

Bacteriological samples were collected in individual sterile bottles, and all other samples were collected with a Sargent sampler; all sampling was done by Public Health Service personnel. Samples for dissolved oxygen were fixed immediately after collection and were titrated later in the laboratory. Samples for other analyses were iced during transportation to the laboratory.



POTOMAC RIVER BASIN
SAMPLING STATION LOCATIONS

FIGURE 1

Table 4

Description of Sampling Station Locations

Location Potomac Basin	Station No.	Description of Location
North Branch		
Patterson Creek	B-1	Bridge on W. Virginia Rt. 28, N.W. of Ft. Ashby, W. Virginia.
South Branch	A-2	Bridge on U.S. 33 near Franklin, W. Virginia.
	A-4	Bridge on U.S. 220 south of Petersburg, W. Virginia.
	A-6	Bridge on U.S. 220 at Welton, W. Virginia.
	A-8	Bridge on U.S 220 north of Moorefield, W. Virginia.
	A-9	Bridge on U.S. 50 above Romney, W. Virginia.
	B-2	Bridge on W. Virginia Rt. 3, east of Springfield, W. Virginia.
North Fork	A-3	Bridge on U.S. 33 at Judy Gap, W. Virginia.
Lunice Creek	A-5	Bridge on U.S. 220 east of Petersburg, W. Virginia (omitted).
South Fork	A-1	Bridge on U.S. 33 near Brandywine, W. Virginia.
	A-7	Bridge on U.S. 220 above Moorefield, W. Virginia.
Potomac River	B-5	Bridge on W. Virginia Rt. 29 at Paw Paw, W. Virginia.
Cacapon River	B-4	Bridge on W. Virginia Rt. 45, 1/2 mile above confluence of North River.
	B-6	Bridge on W. Virginia Rt. 9 near mouth at Great Cacapon, W. Virginia.
North River	B-3	Bridge on W. Virginia Rt. 45 near Forks of Cacapon, W. Virginia.
Potomac River	C-2	Bridge on U.S. 522 at Hancock, Maryland.

Table 4 (Continued)

Description of Sampling Station Locations

Location Potomac Basin	Station No.	Description of Location
L. Tonoloway Creek	C-1	Bridge on U.S. 40 east of Hancock, Maryland
Warm Springs Run	C-3	Bridge on dirt road east off of U.S. 522, 1/2 mile from Hancock Bridge.
Sleepy Creek	C-4	Bridge on W. Virginia 9 about 6 miles east of Berkeley Springs, W. Virginia.
Back Creek	D-1	Bridge on W. Virginia Rt. 45, 1/2 mile east of Glengary, W. Virginia.
	C-5	Bridge on W. Virginia Rt. 9, 1/2 mile west of Hedgesville, W. Virginia.
Potomac River	E-1	River bank at Hagerstown Waterworks intake.
Conococheague Creek	E-4	Bridge off of U.S. 11, south of Chambersburg, Pennsylvania.
	E-3	Bridge on road to Pennsylvania Rt. 416 off of Maryland Rt. 63 at Cearfoss, Maryland.
	E-2	Bridge on Maryland Rt. 68 at Williamsport, Maryland.
Opequon Creek	D-2	Bridge on W. Virginia Rt. 51, 4 miles east of U.S. 11 intersection.
	C-6	Bridge on W. Virginia 45, east of Martinsburg, W. Virginia.
Potomac River	C-7	Bridge on W. Virginia Rt. 48, north of Shepherdstown, W. Virginia.
Antietam Creek	E-5	Bridge on Maryland Rt. 17, northwest of Leitersburg, Maryland.
	E-6	Bridge on U.S. 40A at Funkstown, Maryland.
	E-7	Bridge on Maryland Rt. 68 northwest of Boonsboro, Maryland.

Table 4 (Continued)

Description of Sampling Station Locations

Location Potomac Basin	Station No.	Description of Location
	C-8	Bridge at Antietam, Maryland, 3 miles south of Sharpsburg, Maryland.
Shenandoah River	D-3	Bridge on W. Virginia Rt. 9, 3 miles east of Charles Town, W. Virginia.
	D-8	Bridge on U.S. 340 at Harpers Ferry, W. Virginia.
Potomac River	D-7	Bridge on Maryland Rt. 79 at Brunswick, Maryland.
Catoctin Creek	D-6	Stream bank behind dam on Maryland Rt. 464 between Point of Rocks and Brunswick, Maryland.
Potomac River	D-5	Bridge on U.S. 15 at Point of Rocks, Maryland.
Monocacy River	F-6	Bridge on Maryland Rt. 77, 3 miles west of Keymar, Maryland.
	F-5	Bridge on Maryland Rt. 355 south of Frederick, Maryland.
	F-4	Bridge on Maryland Rt. 28, 2 miles east of U.S. 15.
Rock Creek	F-7	Bridge on U.S. 140 southeast of Gettysburg, Pennsylvania.
Potomac River	D-4	Whites Ferry landing off U.S. 15, 3 miles north of Leesburg, Virginia.

NOTE: Stations F-3 (Muddy Branch), F-1 (Great Falls) and F-2 (Cabin John Creek) were omitted for operational reasons. Water quality data at Great Falls were obtained from the Water Division of the District of Columbia.

At stations where the stream to be sampled was quite wide, a series of dissolved oxygen measurements was made across the stream and at several depths. From these data a point was selected which was representative of average values in the stream at that station, and all subsequent samples were taken at that point. Provisional daily average stream discharge measurements were obtained from the district offices of the U. S. Geological Survey.

All sample analyses except temperature were performed in a Public Health Service mobile laboratory located at the Hagerstown Water Treatment Plant at Williamsport, Maryland. These analyses included a quantitative measurement of dissolved oxygen (D.O.) biochemical oxygen demand (BOD), solids (total, settleable, suspended), pH, alkalinity, dissolved iron, dissolved manganese, tannin and lignin, and coliform group organisms. All tests followed the approved procedures outlined in Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, 10th Edition, except that the tentative method for counting coliform organisms by the membrane filter technique was used instead of the statistical tube test for most probable numbers of coliform organisms.

The significance of each test in evaluating the sanitary quality of a stream is discussed below.

Temperature

The temperature of water controls the oxygen solubility and thus the saturation level of dissolved oxygen in the stream. Since relatively large amounts of dissolved oxygen must be present to maintain a relatively high level of organic waste assimilation, the water temperature is an important criterion in evaluating the sanitary quality of a stream.

pH

pH is defined as the negative logarithm of the hydrogen ion concentration. The pH value indicates the relative acidity or alkalinity of water, with the neutral point at pH 7.0. Values lower than 7.0 indicate the presence of acid salts, and from pH 7.0 to 14.0 the presence of alkalies or alkaline earth salts is indicated.

Dissolved Oxygen (D.O.)

Normally the amount of oxygen dissolved in water of a stream is limited by the saturation value (9.17 ppm at 20°C) which is a function of water temperature, but in some cases as a result of the photosynthetic action of some water plants this value may be exceeded, causing "supersaturation." The saturation value decreases with higher temperatures. Dissolved oxygen must be present to support fish and aquatic life and prevent anaerobic putrefaction of stream waters.

The minimum permissible quantity is dependent on the quality of the water desired. Dissolved oxygen values below the saturation level are an indication of the presence of organic pollution which is utilizing oxygen from the stream water. A measure of the effect of pollution of a particular stream section is given by the deficiency in the dissolved oxygen content below saturation.

Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand of sewage, sewage effluents, polluted waters, or industrial wastes is a measure of the oxygen (in parts per million) required to stabilize decomposable organic matter by aerobic bacterial action. Complete stabilization requires more than 100 days at 20°C, but such long periods of incubation are impracticable in any but research investigations. Consequently, a much shorter period of incubation is used. Incubation for 5 days at 20°C is recommended as the standard procedure and this recommendation was followed during the field study. Conversion of the data from one incubation period to another or from one temperature to another may be approximated. All BOD data included in this report are based on 5-day 20°C BOD unless otherwise noted.

Coliform Group Organisms

This determination is a sensitive indicator of sewage pollution, since it shows the approximate density of organisms that are normally found only in very small numbers in unpolluted streams. Coliform bacteria are normally present in the intestines of warm-blooded animals and are discharged in vast numbers in human feces, which constitute the main source of these bacteria in sewage. The coliform density as determined by the membrane filter test is reported as the estimated number of coliform organisms per 100 milliliters of sample (Direct Membrane Filter Test).

Solids (or Residue)

The solids content of a sample is found by evaporating the sample to dryness and weighing the residue. The total solids are found by drying the unfiltered sample at 103-105°C. The result indicates the total solids present, both organic and inorganic. Ignition of this residue at 500-600°C will remove most of the organic material and water of crystallization, leaving the fixed solids as an indication of the amount of inorganic material present. During the ignition process some of the inorganic material undergoes chemical transformation, however, so that the solids tests cannot be regarded as an absolute determination of the relative amounts of organic and inorganic material present. Filtration of the sample, followed by drying and igniting the residue on the filter, gives the corresponding information on suspended solids. Settleable solids, a part of the suspended solids, are found by allowing a sample to settle for a standard period and then measuring the amount of material settled out.

This test shows the amount of material that can be expected to settle out in a short reach of a slowly flowing stream; the remainder of the suspended solids indicates the amount of material which may be swept downstream for a relatively long distance under the same flow conditions, to be eventually deposited or dissolved depending on the biology and chemistry of the stream. In a swiftly flowing stream all the suspended solids may be swept far downstream from the source of pollution before being deposited.

Color, Tannin, and Lignins

The color of natural waters is due to dissolved or colloidal substances of vegetable origin extracted from leaves, peaty matter and other similar material. It consists of tannins, glucosides, and their derivatives as well as iron and other substances. These substances have detrimental effects on water distribution systems and should be removed before the water is used for municipal supplies. This removal usually requires difficult and costly treatment. Tannins and lignins (measured here as tannins) are a part of the coloring material; they result from the partial decomposition of cellulosic material. The color these substances impart is quite intense and persists for many miles in a stream. If a large proportion of the tannins and lignins in a watercourse can be traced to one source, the persistence downstream of the waste containing them can be measured by this test. Both of these determinations are made by colorimetric comparison of the sample with standard solutions.

Alkalinity

The alkalinity of water, which may be defined as its capacity for neutralizing acid, is usually due to the presence of bicarbonate and carbonate ions. Hydroxide, borate, silicate, or phosphate ions also contribute to alkalinity. Alkalinity is determined by titration with dilute sulfuric acid to an end point of pH 4.0. In this study all titrations for alkalinity were performed electrometrically.

Iron and Manganese

These metals can be precipitated in distribution systems causing incrustation of pipes and discoloration of the water. Some iron and manganese is present in most natural waters, and is usually present in large quantity in acid mine water. They are determined colorimetrically.

PRESENTATION OF DATA

DESCRIPTION OF AREA INVESTIGATED

The total drainage area of the Potomac River at its mouth is 14,670 square miles. This report, however, involves water supply, waste disposal, and water quality aspects existing above Great Falls or within an area of about 11,500 square miles. All municipalities and industries of reasonable size within this area are reported. The streams that were sampled for water quality evaluations are those along which significant industries and municipalities are located and/or those possessing possible reservoir sites. With the exception of Patterson Creek of the North Branch, the North Branch was not included in the 1958 sampling program; nor were portions of the Shenandoah River and Opequon Creek located in Virginia. The drainage area comprising these sampling omissions amounts to approximately 4,200 square miles.

The sub-basin drainage areas and major streams sampled for water quality evaluations are shown in Table 5.

Table 5

Sub-Basin Drainage Areas and Streams Sampled
During Potomac Basin Study

Sub-Basin of Potomac	Miles to Mouth (Potomac)	Drainage Area (Sq. Mi.) Total	Md.	Pa.	Va.[1]	W. Va.
North Branch	285	1,328	218	246		349
Patterson Creek*	285, 9	290				290
South Branch*	285	1,493			109	1,384
Town Creek	282	156	67	89		
Little Cacapon Creek	280	108				108
Fifteen Mile Creek	257	61	49	12		
Sideling Hill Creek	251	104	23	81		
Cacapon River*	248	683				683
Little Tonoloway Creek*	239	26	16	10		
Great Tonoloway Creek	237	114	2	112		
Warm Springs Run*	236	20				20
Sleepy Creek*	233	143			20	123
Licking Creek	231	214	27	187		
Back Creek*	226	273			163	110
L. Conococheague Creek	217	18	16	2		
Conococheague Creek*	211	563	65	498		
Opequon Creek*	202	345			156	189
Antietam Creek*	180	292	187	105		
Potomac River above mouth of the Shenandoah River*	171-265	6,308	1,119	1,342	429	3,418
Shenandoah River*	171	3,054			2,982	72

Table 5 (Continued)

Sub-Basin Drainage Areas and Stream Sampled
During Potomac Basin Study

Sub-Basin of Potomac	Miles to Mouth (Potomac)	Drainage Area (Sq. Mi.) Total	Md.	Pa.	Va.[1]	W. Va.
Catoctin Creek (Md.)*	162	121	121			
Catoctin Creek (Va.)	160	-			-	
Tuscarora Creek	155	24	24			
Monocacy River*	153	970	742	228		
Goose Creek	142	385			385	
Seneca Creek	135	129	129			
Sugarland Creek	134	-			-	
Muddy Branch Creek	132	-			-	
Potomac River - Great Falls[2]	127-285	11,532				
Difficult Run	124	-			-	
Cabin John Creek	118	-	-			
Potomac River at Washington, D. C.	110-285	11,677	2,435	1,570	4,182	3,490

*Tributaries and stream sections sampled for water quality evaluations.

1 - No samples collected in Virginia.

2 - Sampled to Whites Ferry. (Water quality data at Great Falls were obtained from the Water Division of the District of Columbia records at Dalecarlia Reservoir.)

HYDROMETRIC DATA

The investigation was conducted at a time when stream flows were sufficiently low to permit measurements of the degree of critical water quality. Stream flows corresponding to survey sampling data are shown in Appendix IV. The magnitude of flows encountered during the survey and the recorded average, maximum, and minimum flows for the tributary streams and stream sections of Potomac River sampled are shown in Table 6. Graphical representations of the survey flows compared with average recorded flows for the Potomac River are shown in Figure 2.

Table 6

Provisional Survey Stream Flows and
Published U.S.G.S. Flow Records

Tributary Sampled[1] (Potomac)	Survey Flows (cfs)[2] Ave.	Max.	Min.	Recorded Flows (cfs)[3] Ave.	Max.	Min.
Patterson Creek	8.2	11	7.9	165	16,000	2.5
South Branch	165	242	113	1,273	143,000	50
Cacapon River	67	[illegible]	58	578	87,600	35
Little Tonoloway Cr.	0.8	2	0.1	17.7	1,470	0
Warm Springs Run[4]	3	-	-	-	-	-
Sleepy Creek	-	-	-	-	-	-
Back Creek	13	19	11	204	22,400	0.9
Conococheague Creek	110	168	106	579	17,100	25
Opequon Creek	77	100	60	224	9,100	25
Antietam Creek	134	200	110	261	7,720	35
Shenandoah River	760	990	560	2,588	230,000	59
Catoctin Creek	9.8	18	6	83	7,760	1.5
Monocacy River	243	649	111	920	51,000	35
Main Stem						
Paw Paw, W. Va.	444	585	357	3,164	240,000	216
Hancock, Md.	533	733	351	4,104	340,000	180
Point of Rocks	1,990	2,250	1,570	9,436	480,000	540
Near Wash.,D.C.*	2,330	2,480	1,720	11,340	484,000	782

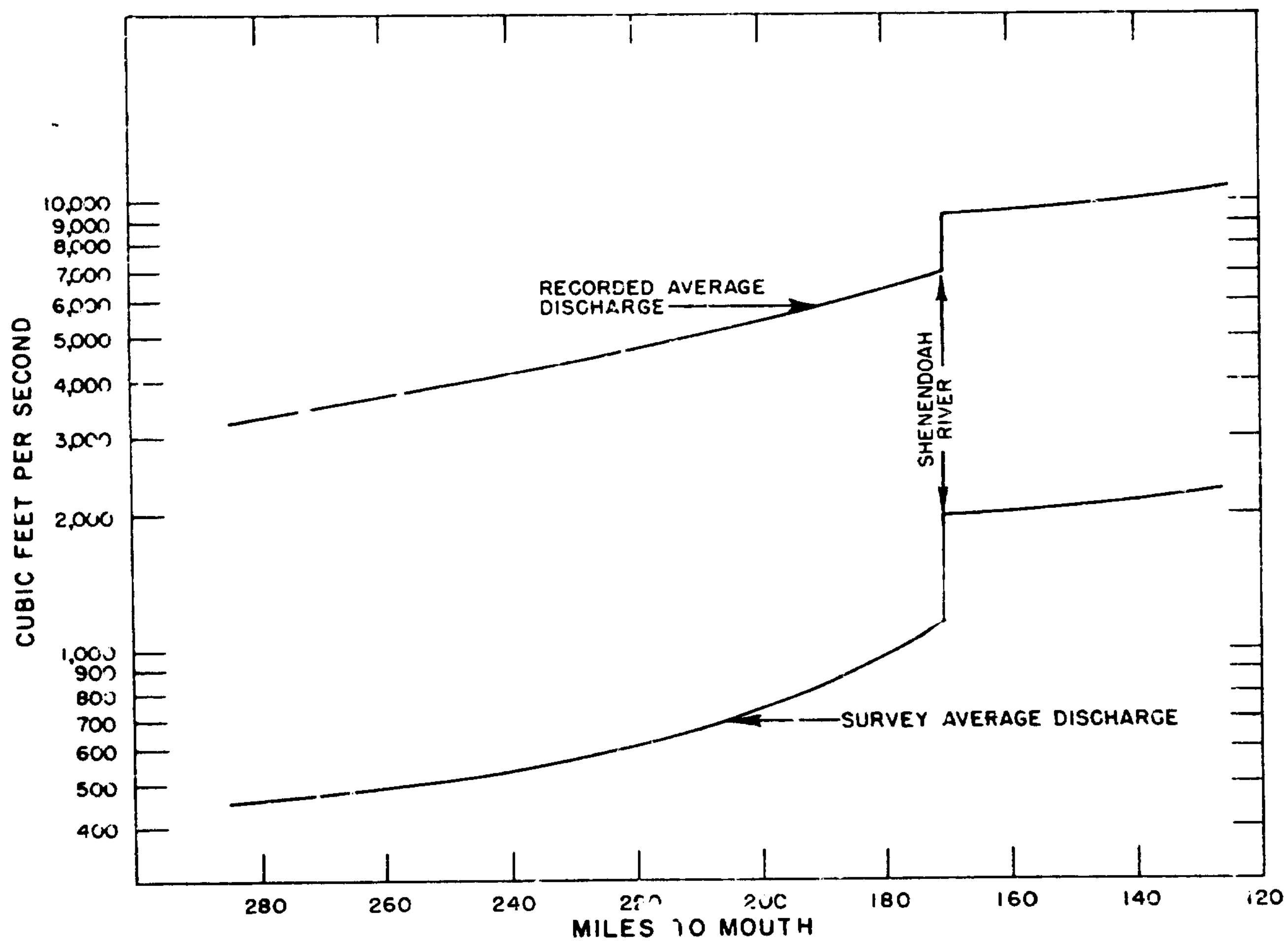
1 - Flow at lower-most gaging stations on respective tributaries except where otherwise indicated.

2 - Provisional flows corresponding to days sampled.

3 - Published flows recorded through water year 1955.

4 - Measured during survey.

* Includes diversions at Great Falls for water supply. Diversions during survey were approximately 320 cfs. Diversion corresponding to recorded minimum flow was 334 cfs.



POTOMAC RIVER
DISCHARGE PATTERN BETWEEN CONFLUENCE
NORTH AND SOUTH BRANCHES AND GREAT FALLS

FIGURE 2

WATER AND WASTES

The types of industrial activity characterizing the economy of the Upper Potomac River Basin necessitate the use of relatively large quantities of water. Nearly all of the manufactured or processed materials produced in the basin require water of high quality and constant supply. The spent waters or fluid wastes from such activities contain certain materials which, upon discharge to the stream, can affect the normal biological habitat and reduce the suitability of water for downstream uses. Allied with industrial areas are the needs for high quality water for domestic purposes. Wastes arise from this source in the form of domestic sewage which, combined in the stream with industrial wastes, further reduces the suitability of these waters for use at downstream locations.

According to the compilation of recent information from the states and communities involved in the Potomac Basin Study, together with estimates where information was lacking, the quantity of water used for industrial processing is nearly three times the amount used for domestic purposes. It is also found that the industrial waste loads estimated in terms of domestic sewage equivalents (decomposable organic materials) is approximately two and one half times that of domestic sewage after all forms and degrees of treatment have been applied.

In addition to organic type wastes, there are numerous disposals of inorganic industrial wastes (non-decomposable materials) to the waterways of the Potomac Basin. Areas significantly polluted by organic, inorganic, and bacterial contaminants are identified and described in a later section dealing with water quality and survey sampling evaluations.

Water Uses and Sources

Domestic

There are approximately 412,000 persons residing in urban areas along the waterways of the Potomac Basin above Great Falls who are served by municipal or privately owned water systems (see Appendix I). Water use for domestic purposes in the basin averages approximately 56.5 mgd, or an average per capita use of 137 gpd. Of this amount of water, approximately 80 per cent is obtained from surface sources, the balance being taken from wells and springs as ground water. Table 7 shows the quantities and sources of water used for domestic purposes in the sub-basins and main stem of the Potomac River above Great Falls.

Table 7

Potomac Basin
Domestic Water Supply Summary

Sub-Basin (Potomac)	Population Served	Ground Water (GPD)	Surface Water (GPD)
North Branch			
Savage River	16,080	500,000	1,445,000
Georges Creek	4,757	-	572,000
New Creek	7,000	-	500,000
Wills Creek	1,919	46,000	105,000
Evitts Creek	61,000	-	15,750,000
Patterson Creek	1,550	194,000	-
Main Stem	1,376	157,000	-
South Branch			
North Fork	None	-	-
South Fork	1,625	-	168,000
Main Stem	5,500	50,000	390,000
Cacapon River	780	20,000	-
Little Tonoloway Creek	1,000	-	400,000
Great Tonoloway Creek	-	-	-
Warm Springs Run	975	190,000	-
Sleepy Creek	-	-	-
Licking Creek	-	-	-
Back Creek	570	70,000	-
Conococheague Creek	23,900	481,000	2,210,000
Opequon Creek	21,210	2,811,000	-
Antietam Creek	35,832	550,000	4,345,000
Shenandoah River			
North Fork	23,654	-	3,836,000
South Fork	85,241	2,373,000	6,123,000
Main Stem	6,650	517,000	210,000
Catoctin Creek - Md.	1,376	169,000	-
Catoctin Creek - Va.	1,533	191,000	-
Tuscarora Creek	None	-	-
Monocacy River	50,833	1,419,000	4,657,000
Goose Creek	3,208	351,000	221,000
Seneca Creek	None	-	-
Sugarland Creek	1,210	146,000	-
Muddy Branch Creek	4,000	-	500,000
Potomac River above Great Falls and Washington, D. C. water supply intake	49,499	621,000	4,245,000

Industrial Processing

There are about twenty-five types of industrial activities in the Potomac Basin in which water of significant quantities is used for processing, cooling, and manufacturing. The total industrial use

of water for other than power production averages approximately 150 mgd. Most of the water used by industry (90 per cent) is obtained from surface sources either directly from the stream or from municipalities supplied by surface water. The remaining 10 per cent is taken from wells and springs as ground water (see Table 8). Individual industrial uses are shown in Appendix I.

Industrial Cooling

There are eighteen steam-electric power plants in the Potomac Basin, each of which use large quantities of water for cooling purposes. The estimated quantity of water used for cooling purposes is 390 mgd. Essentially all water used is obtained from surface sources (see Table 8).

Table 8

Potomac Basin
Industrial Water Supply Summary

Sub-Basin[1] (Potomac)	Process Water		Cooling Water
	Ground (GPD)	Surface (GPD)	Surface (GPD)
North Branch			
Georges Creek	-	1,000,000	-
New Creek	-	35,000	-
Wills Creek	-	288,000	-
Evitts Creek	-	2,244,000	-
Main Stem	35,000	93,300,000	92,900,000
South Branch			
South Fork	2,000	235,000	-
Warm Spring Run	18,000	180,000	-
Conococheague Creek	412,000	585,000	2,500,000
Opequon Creek	1,065,000	65,000	-
Antietam Creek	-	18,600,000	34,440,000
Shenandoah River			
North Fork	-	750,000	1,500,000
South Fork	6,735,000	20,000,000	8,070,000
Main Stem (W.Va.)	2,945,000	530,000	72,310,000
Catoctin Creek, Va.	110,000	-	-
Monocacy River	499,000	566,000	-
Potomac River	1,000	1,646,000	178,970,000

[1] All Sub-basins not appearing in the table contain no significant water-using industries.

Hydroelectric Power

Eighteen hydroelectric power plants in the Potomac Basin use various portions of the streams to produce electrical energy, totaling about 15,000 horsepower. Table 9 shows the locations and horsepower ratings of these power units.

Table 9

Potomac Basin
Hydroelectric Power Summary

Sub-Basin (Potomac)	Number of Plants	Rating H.P.
South Branch	1	565
Cacapon River	1	1,120
Great Tonoloway Creek	1	No record
Antietam Creek	1	360
Shenandoah River		
North Fork	3	690
South Fork	6	5,803
Main Stem	1	1,840
Goose Creek	1	800
Potomac River	3	3,142

Recreation

The extent to which a stream supports fish life and fishing can often be used as a barometer for determining its recreational value, although boating and water sports are becoming increasingly important recreational activities. It is reported that fishermen travel many miles to fish in the upper West Virginia portion of the basin except the North Branch. The South Branch and Cacapon River are known throughout West Virginia and surrounding states for their good fishing waters. Fishing of lesser intensity has been observed on the main stem of the Potomac at Hancock, Williamsport, Point of Rocks, and Brunswick. The value of fishing to the State of West Virginia is realized by the sizable return each year from the licenses sold to fishermen using various portions of the waters of the Potomac Basin for fishing purposes.

Some of the streams, particularly in West Virginia, serve as locations for summer camping and as sites for family cabins and large industrial and welfare camps. Boating and swimming are often a part of the camping use.

Boating and swimming have been observed at Shepherdstown and water skiing at Williamsport. It is estimated that approximately 1,000 boats have been tied up along the Potomac River near Falling Waters. Activities in the Falling Waters area are boating, swimming, fishing, and water skiing.

Wastes and Waste Loads

Domestic Sewage

It is estimated that 350,000 persons or about 85 per cent of those served by water systems along the waterways of the Potomac

Basin are served by sewage collection systems. The total quantity of treated and raw domestic sewage discharged to water courses of the basin is equivalent to a population of approximately 210,000 persons. The reduction in biochemical oxygen demand attributable to sewage treatment facilities is about 40 per cent. Table 10 shows the sewered populations, volume of waste discharged, and population equivalents discharged after treatment where applicable for the sub-basins summarized. A complete list of all significant sources of domestic sewage is given in Appendix II.

Table 10

Potomac Basin
Domestic Sewage Summary

Sub-Basin (Potomac)	Sewered Population	Quantity Disch. GPD	Population Equiv. Disch.
North Branch			
Savage River	-	-	-
George Creek	8,232	1,030,000	3,072
New Creek	-	-	-
Wills Creek	1,850	146,000	1,850
Evitts Creek	-	-	-
Patterson Creek	1,395	174,000	1,145
Main Stem	61,695	11,500,000	59,815
South Branch			
North Fork	-	-	-
South Fork	1,075	108,000	1,075
Main Stem	3,740	293,000	1,970
Cacapon River	780	20,000	390
Little Tonoloway	-	-	-
Great Tonoloway	-	-	-
Warm Spring Run	925	175,000	925
Sleepy Creek	-	-	-
Licking Creek	-	-	-
Back Creek	515	63,000	515
Conococheague Creek	27,340	2,457,000	18,076
Opequon Creek	35,445	5,272,000	17,930
Antietam Creek	57,622	6,924,000	11,570
Shenandoah River			
North Fork	6,390	824,000	6,095
South Fork	72,165	7,944,000	36,957
Main Stem	3,160	346,000	2,030
Catoctin Creek, Md.	840	105,000	550
Catoctin Creek, Va.	1,150	142,000	650
Tuscarora Creek	-	-	-
Monocacy River	45,317	5,585,000	30,725
Goose Creek	2,995	338,000	753

Table 10 (Continued)

Potomac Basin
Domestic Sewage Summary

Sub-Basin (Potomac)	Sewered Population	Quanitiy Disch. GPD	Population Equiv. Disch.
Seneca Creek	-	-	-
Sugarland Creek	1,100	132,000	275
Muddy Branch Creek	4,000	500,000	1,000
Potomac River above Great Falls	12,599	1,423,000	9,905

Industrial Wastes

There are approximately forty-five industries in the Potomac Basin from which waste effluents containing varying amounts of organic substances are discharged to the basin waterways. The organic load as measured in terms of biochemical oxygen demand after various forms of treatment is equivalent to a raw sewage load from a population of approximately 518,000 persons. The types of organic wastes comprising the major industrial waste loads together with corresponding population equivalents discharged are as follows:

Type Wastes (Organic)	Population Equivalents Discharged
Pulp and Paper	300,000
Synthetic	100,000
Textile	16,000
Pharmaceutical	31,500
Tannery	27,500
Cannery	18,850
Poultry	13,150
Dairy	6,700
Slaughter	4,600

Approximately thirty-five industries, including several of the above types, discharge wastes containing inorganic substances. The following is a list of the types of industries located in the Potomac Basin from which wastes containing inorganic substances originate:

Type of Industry	Inorganic Waste
Pulp and Paper Manufacturing	Residual process chemicals, heat
Tanning	" " " "
Textile	" " " "
Chemical	" " " "
Pharmaceutical	" " " "

Type of Industry	Inorganic Waste
Metal Plating	Residual process chemicals, heat
Aircraft Manufacturing	" " " "
Explosives Manufacturing	" " " "
Synthetics Manufacturing	Fines, chemicals, fly ash, heat
Plate Glass Manufacturing	Grinding and polishing fines
Glass-Sand Manufacturing	Glass-sand fines
Cement Manufacturing	Silt and clay
Sand and Gravel	" " "
Limestone	" " "
Coal Mining	Silt, fines, acids
Electrical Power	Fly ash, slag, heat

Miscellaneous types of waste originate from railroad yards (washing and degreasing), laundries (soaps and detergents), and rubber products manufacturing (carbon black).

The industrial wastes and organic waste loads discharged to the waters of various sub-basin areas of the Potomac Basin are summarized in Table 11. A complete list of the sources and quantities of industrial wastes are given in Appendix II.

WATER QUALITY

Water Quality Criteria

In order to describe relative water quality in the Potomac Basin and identify streams or stream sections containing water of questionable quality for water supply purposes, the water quality criteria as adopted by the Interstate Commission on the Potomac River Basin are used. Table 11 shows the stream use classifications based upon these water quality criteria.

The criteria for Class C water shown in Table 12 are used in identifying the stream sections containing water of suitable or questionable quality for domestic supplies and industrial processing.

General

According to sampling data obtained in 1958, the quality of water in the portions of the Potomac Basin studied generally reflected degrees of pollution associated with respective densities of municipal and industrial development. The Potomac River and tributaries above Hancock, Maryland, excluding the North Branch (covered in the recent report on the North Branch Potomac River, August 1957), except for several local areas, contained water of suitable quality for domestic and industrial use and provided a suitable habitat for the normal propagation of aquatic life. The Potomac River and

several tributaries between Hancock and Great Falls, Maryland, contained zones of questionable water quality as identified by various pollution characteristics. Significant pollution was found downstream from sewage and industrial waste discharges on the South Branch Potomac, Conococheague Creek, Opequon Creek, Antietam Creek, and the Monocacy River. Sampling data collected near the mouth of the Shenandoah River indicated excessive pollution in that area. Pollution of somewhat lesser magnitude and of domestic origin was indicated at the lower extremities of Patterson Creek, Little Tonoloway Creek, and Catoctin Creek. Warm Springs Run was grossly polluted by glass-sand wastes which, upon discharge to the Potomac River, adversely affected the water quality and aquatic environment of the Potomac River for many miles downstream.

The water quality parameters that are used to identify and describe the suitability of water for domestic and industrial use in the portions of the Potomac Basin studied are those coinciding with the objectives previously outlined for Class C water which ultimately are associated with pollution characteristics. These parameters are namely: coliform group organisms, biochemical oxygen demand, and dissolved oxygen. Generally, the pH, alkalinity, hardness, turbidity, and solids contents of most waters examined, unless otherwise indicated, were of reasonable magnitude (see Appendix III). Dissolved iron and manganese and phenolic compounds are noted where concentrations exceed limits recommended in Public Health Service Drinking Water Standards, Vol. 61, No. 11, 1956, to indicate needs for treatment facilities to reduce the concentration of these substances.

Survey Sampling Data

Figure 3 shows the magnitude of coliform group organisms found at the respective stream sampling stations relative to criteria for Class C water as established by the Interstate Commission on the Potomac River Basin. The higher values shown represent nearly maximum bacterial pollution of the various streams and stream sections by virtue of the close proximity of sampling stations downstream from waste sources.

The tributary sampling stations in the lower portions of the Potomac Basin revealed significantly higher concentrations of biochemical oxygen demand than were found at most of the upper basin stations. From a basinwide standpoint the higher BOD found in the lower basin generally indicates a compounding of BOD from greater numbers of municipal, industrial, and agricultural sources common to this portion of the basin (see Figure 4). A similar comparison of BOD concentrations was found between upstream and downstream stations on the main stem of the Potomac River as also shown in Figure 4. The BOD distribution and load pattern approximated for the main stem of the Potomac River is shown in a later section in which water quality and degree of pollution are discussed.

Table 11

Potomac Basin
Industrial Waste Summary

Sub-Basin[1] (Potomac)	Type of Industry	Population Equiv. Discharged[2]
North Branch	Pulp and Paper, Tanning Cellulose, Dairy, Laundry, Coal, Glass, Rubber Products, Cement, Electrical Power	362,740 (Plus inorganics and heat)
South Branch		
South Fork	Tannery, Poultry	6,050
Warm Springs Run	Cannery, Sand-Glass	900 (Plus inorganics)
Back Creek	Sand and Gravel	(Inorganics)
Conococheague Creek	Canning, Paper, Tanning Explosives, Electrical Power	19,450 (Plus inorganics and heat)
Opequon Creek	Canning, Limestone, Woolen	9,000
Antietam Creek	Slaughter, Aircraft, Cement, Railroad, Electric Power	1,000 (Plus inorganics and heat)
Shenandoah River	Synthetics, Textiles, Pharmaceuticals, Tannery, Slaughter, Poultry, Paper Box-board, Limestone, Electric Power	110,000 (Plus inorganics and heat)
Catoctin Creek, Va.	Slaughter	265
Monocacy River	Canning, Poultry, Dairy, Slaughter, Rubber Products, Plating, Sand and Gravel	13,580 (Plus inorganics and heat)
Potomac River	Explosives, Sand and Gravel, Railroad, Electric Power	(Inorganics and heat)

1 - All sub-basins not appearing in the table contain no significant industrial waste sources.

2 - Values reflect treatment where applicable at the various industrial locations.

TABLE 12

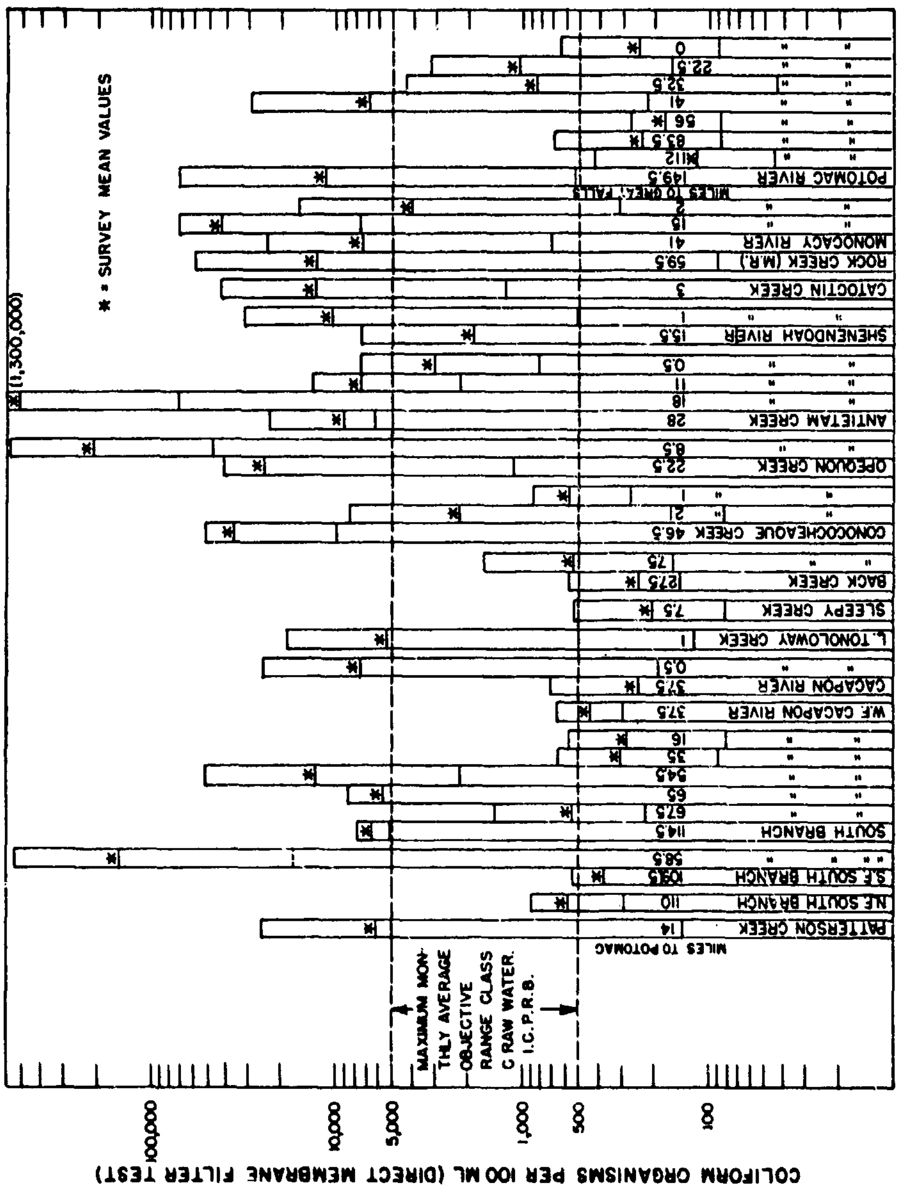
Interstate Commission on the Potomac River Basin

Minimum water Quality Criteria for Streams
in the Potomac River Basin

Approved 8 August 1946

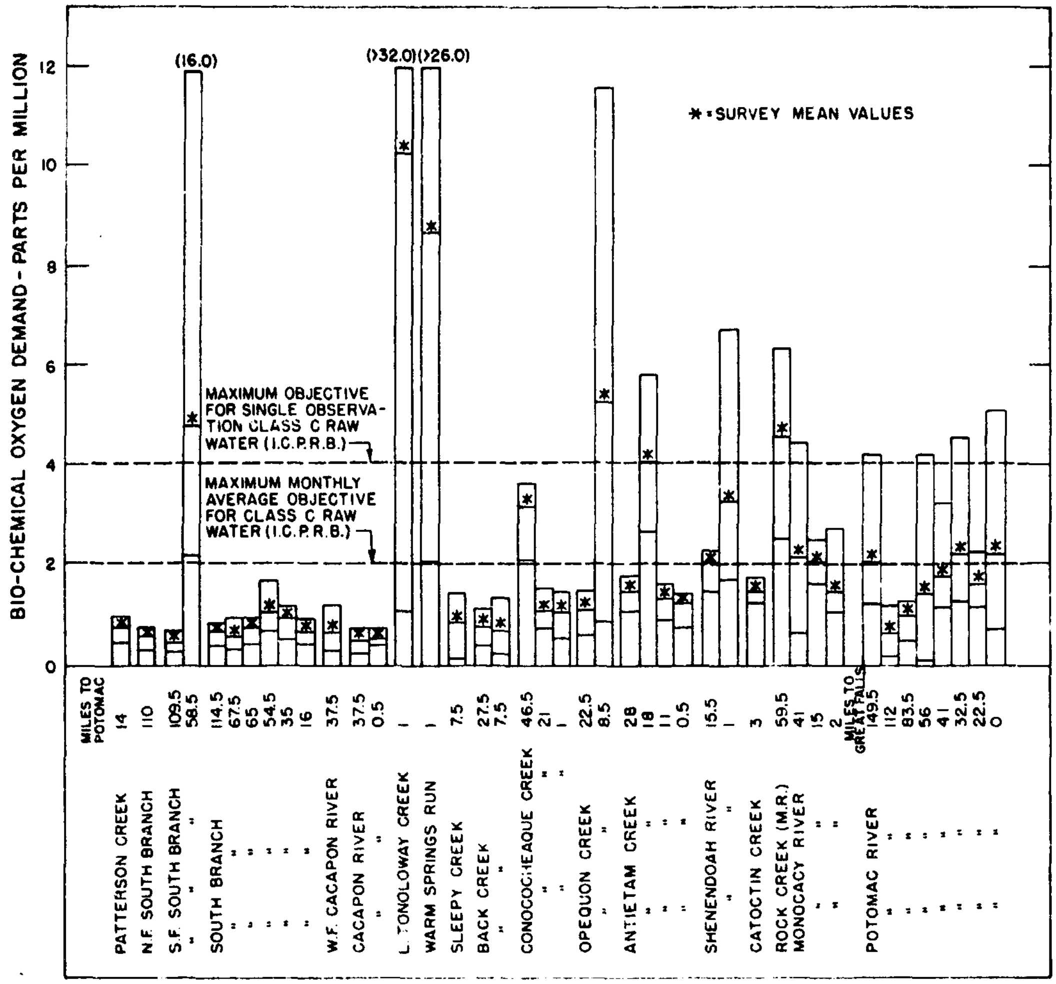
	CLASS A Drinking Water (No treatment except cl.)	CLASS B Bathing, Fish Life	CLASS C Domestic Water Supplies (Before complete treatment) Industrial Process Water	CLASS D General Sanitary Condition - to prevent nuisance
Coliform Bacteria	0 - 50	Mo. av. 50 - 500 Max. not over 1,000	Mo. av. 500 - 5,000	----------
Color, ppm	0 - 10	20 (desirable)	Amt. of color and turbidity allowed which can be removed by standard equipment and practices	----------
Turbidity, ppm	0 - 10	40 (desirable)	----------	----------
pH	6.0 - 8.0	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
5-Day BOD, ppm	----------			
Monthly av., ppm	----------	1.5	2.0	3.0
Max. observation, ppm	----------	3.0	4.0	5.0
Dissolved Oxygen, ppm				4.0
Monthly av., ppm	7.5	6.5	6.5	Min. daily ave. 3.0
Min. observation, ppm	6.5	5.0	5.0	Absolute min. 2.0
Other Conditions	No toxic substances, oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste - or odor-producing substances.	Same as A	Same as A	No toxic substances, oils, tars, or free acid at any time. No floating solids or debris except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

NOTE: These criteria are to be used only in conjunction with a sanitary survey as a guide in determining the minimum water quality for the various classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.



POTOMAC RIVER
MEAN, MAXIMUM AND MINIMUM COLIFORM ORGANISMS
RELATIVE TO DOMESTIC AND INDUSTRIAL WATER QUALITY CRITERIA
SEPTEMBER-OCTOBER 1958

FIGURE 3



POTOMAC RIVER BASIN
MEAN, MAXIMUM AND MINIMUM BIO-CHEMICAL OXYGEN DEMAND
RELATIVE TO DOMESTIC AND INDUSTRIAL WATER QUALITY CRITERIA
SEPTEMBER-OCTOBER 1958

FIGURE 4

Dissolved oxygen concentrations at most sampling stations were well above the minimum levels established by the Interstate Commission on the Potomac River Basin. Marginal concentrations of dissolved oxygen, however, occurred in the South Fork of the South Branch at Moorefield, West Virginia; Opequon Creek below Martinsburg, West Virginia; Antietam Creek below Hagerstown, Maryland; and the Monocacy River below Frederick, Maryland. Two locations--Conococheague Creek below Chambersburg, Pennsylvania and Rock Creek of the Monocacy River below Gettysburg, Pennsylvania--contained dissolved oxygen concentrations much lower than the minimum average level established by the Interstate Commission (see Figure 5).

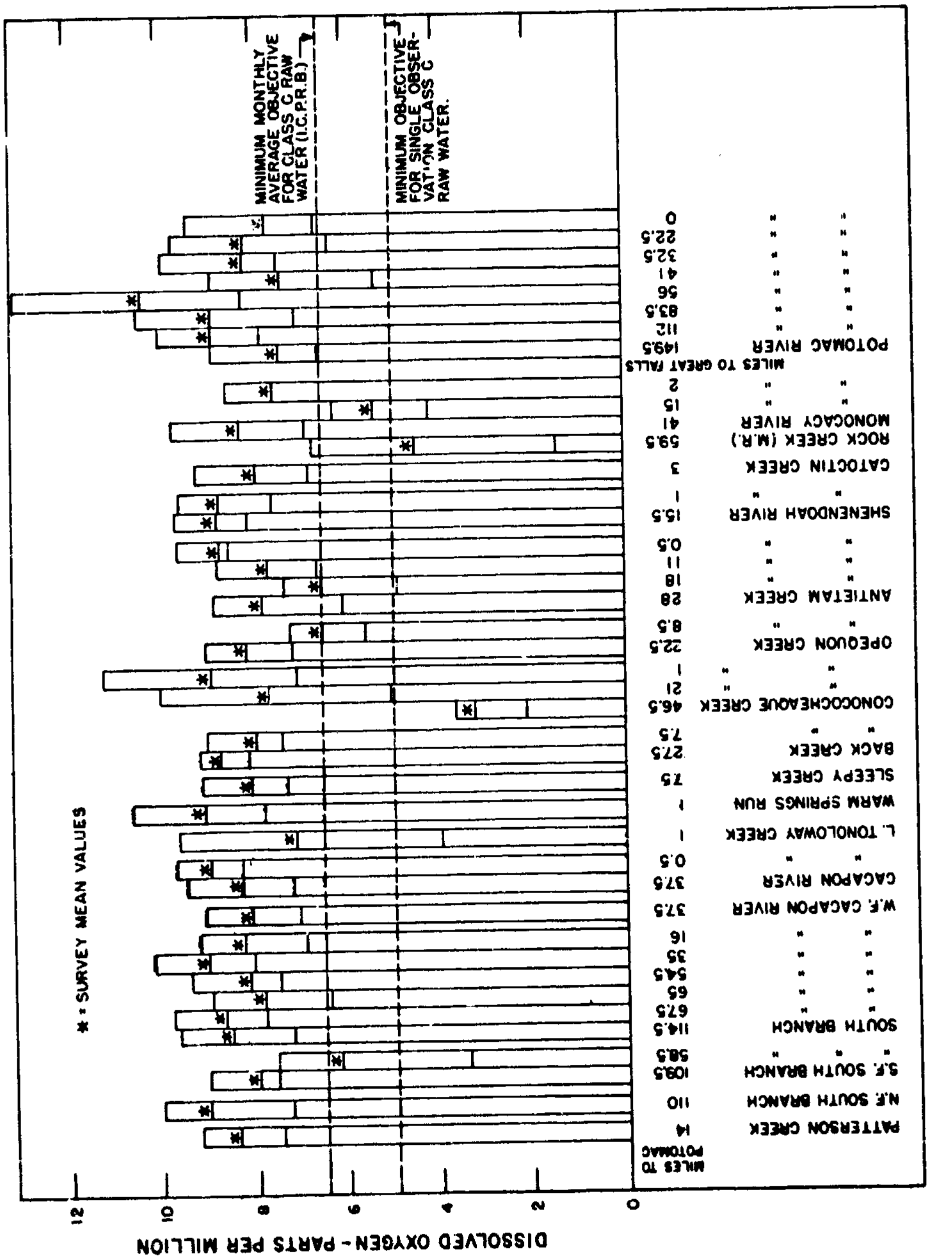
The sampling stations which revealed one or more characteristics inconsistent with the water quality objectives for Class C water, together with pertinent data involved, are shown in Table 13 (see complete data in Appendix III).

The results shown in Table 13 are indicative of conditions existing during relatively low stream flow (see Appendix IV). Intermediate sampling points below critically polluted zones revealed rather rapid recovery to generally satisfactory quality. Recovery within relatively short distances of stream travel is attributed to the riffle and pool characteristics of many Potomac Basin streams which, at times of low flow, provide excellent stream reaeration essential for rapid organic stabilization and sedimentation pools for solids deposition. Pool areas, however, are not always beneficial. Heavy depositing of organic material can result in the formation of septic sludge banks. Several instances of this phenomenon were observed in the North Branch of the Potomac as described in the report on that portion of the Basin. Silt, clay, and organic materials deposited in pool areas at times of low stream flow become the source of part of the material flushed downstream during increased stream flow. An example of the effect of variable stream discharges on turbidity and total bacteria as occur at the Hagerstown Water Treatment Plant is shown in Figures 6 and 7, respectively.

<u>Observed Stream Conditions</u>

Biological examinations of the Potomac River and its tributaries revealed generally good quality water in most stream sections with the exception of several local areas. Planktonic and filamentous algae and higher aquatic plants associated with waters where organic pollution is minimal were found. The main stem of the Potomac River was essentially unpolluted from the biological standpoint except for approximately ten miles of river below the mouth of Warm Springs Run. Heavy deposits of glass-sand fines from the glass-sand operation on Warm Springs Run literally destroyed most of the bottom flora throughout this reach.

At Moorefield, West Virginia (South Fork of the South Branch), the stream bed contained heavy Sphaerotilus growths (filamentous slime).



POTOMAC RIVER BASIN
MEAN, MAXIMUM AND MINIMUM DISSOLVED OXYGEN
RELATIVE TO DOMESTIC AND INDUSTRIAL WATER QUALITY CRITERIA
SEPTEMBER-OCTOBER 1958

FIGURE 5

TABLE 13

Survey Sampling Stations Showing One or More Characteristics Inconsistent with Water Quality Objectives for Class C Water

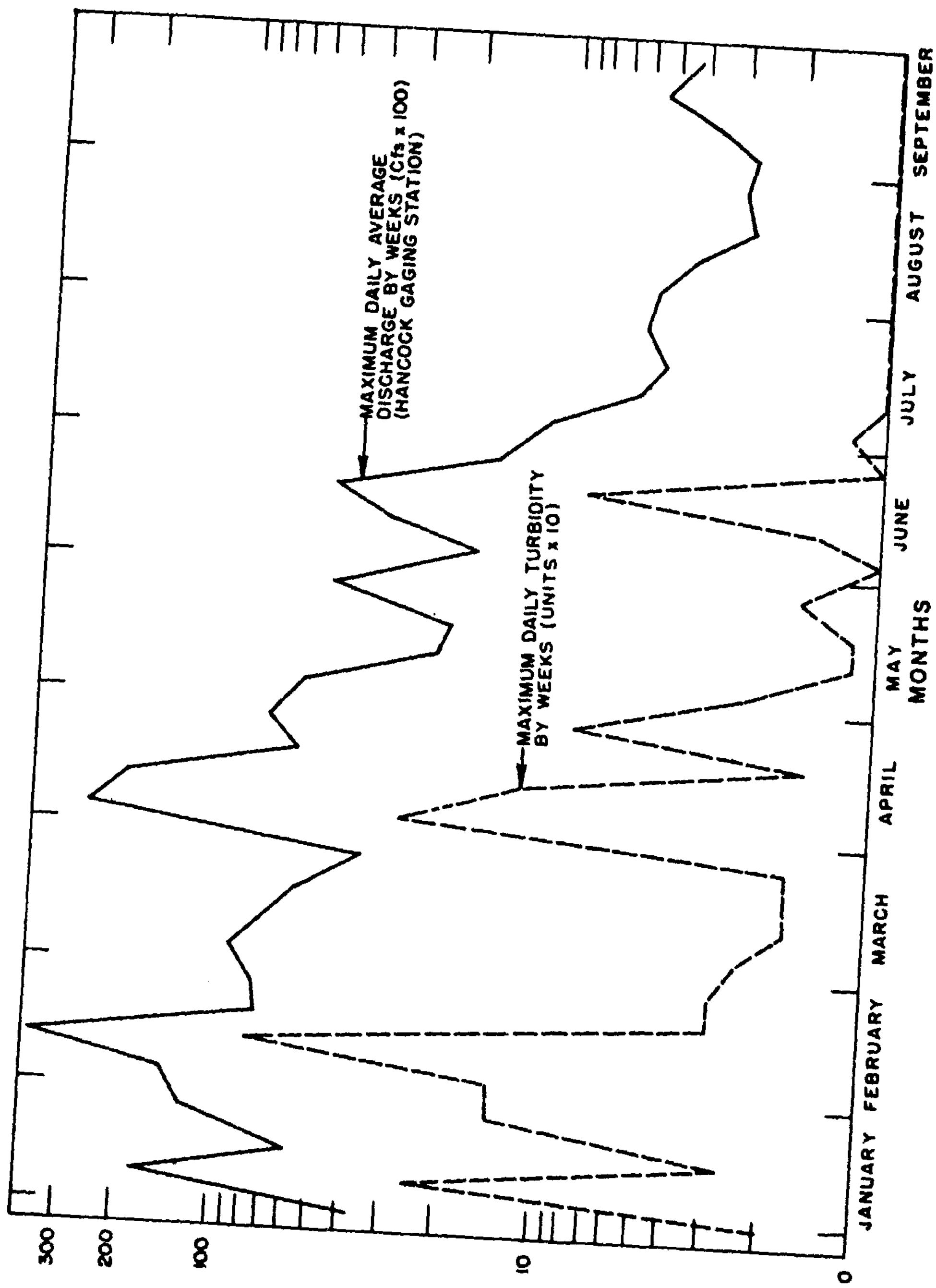
Name of Stream and Station Location	No. of Samples	D.O., ppm Ave.	D.O., ppm Max.	D.O., ppm Min.	BOD, ppm Ave.	BOD, ppm Max.	BOD, ppm Min.	Coli./100 ml. Ave.	Coli./100 ml. Max.	Coli./100 ml. Min.	Other Ave.	Other Max.	Other Min.
Patterson Cr., North Br. Potomac At Fort Ashby, W. Va.	6	8.45	9.30	7.50	0.68	0.90	0.45	5,980	> 25,000	130			
South Fork, South Br. Potomac At Moorefield, W. Va.	6	6.20	7.60	3.40	4.82	16.00	2.20	140,800	550,000	17,000	Tannin, ppm* 6.94	22.40	2.10
South Br. Potomac Below Moorefield, W. Va. (3 mi.)	6	8.15	9.40	7.50	1.12	1.75	0.65	13,000	51,000	2,300	Tannin, ppm* 0.88	2.25	0.50
Warm Springs Run Above mouth (1 mi.)	13	9.10	10.70	7.85	8.70	> 26.80	2.05	-	-	-	Turbidity - units 10,500	50,000	130
											Total Solids, ppm 11,770	52,500	255
Conococheague Cr. Below Chambersburg, Pa. (8 mi.)	6	3.27	3.65	2.10	3.24	3.70	2.15	37,700	52,000	10,000			
Conococheague Cr. Below Pa. border (1 mi.) Below Mercersburg, Pa. (21 mi.) Below Chambersburg, Pa. (30 mi.)	6	7.71	10.10	5.05	1.16	1.55	0.80	2,350	7,700	80	Tannin, ppm* 0.86	1.00	0.75
Opequon Cr. Below Virginia border (7 mi.) Below Winchester, Va. (24 mi.)	6	8.21	9.10	7.20	1.16	1.55	0.60	24,500	42,000	1,100			
Opequon Cr. Below Tuscarora Cr. (1 mi.) Below Martinsburg, W. Va. (3 mi.)	6	6.48	7.25	5.60	5.28	11.60	0.90	216,000	590,000	47,000	Turbidity - units 540 (2 samples)		
Antietam Cr. At Funkstown, Md. Below Hagerstown, Md. (1 mi.)	6	6.56	7.40	3.90	4.08	5.85	2.75	505,500	1,300,000	70,000			
Antietam Cr. Below Hagerstown, Md. (3 mi.)	6	7.76	8.80	6.65	1.39	1.70	0.95	7,100	13,000	2,100			
Antietam Cr. Below Hagerstown, Md. (18 mi.) Above mouth (0.5 mi.)	6	8.82	9.70	8.1[illegible]	1.23	1.85	0.80	2,900	7,200	800			

TABLE 13 (Cont'd)

Survey Sampling Stations Showing One or More Characteristics
Inconsistent with Water Quality Objectives for Class C Water

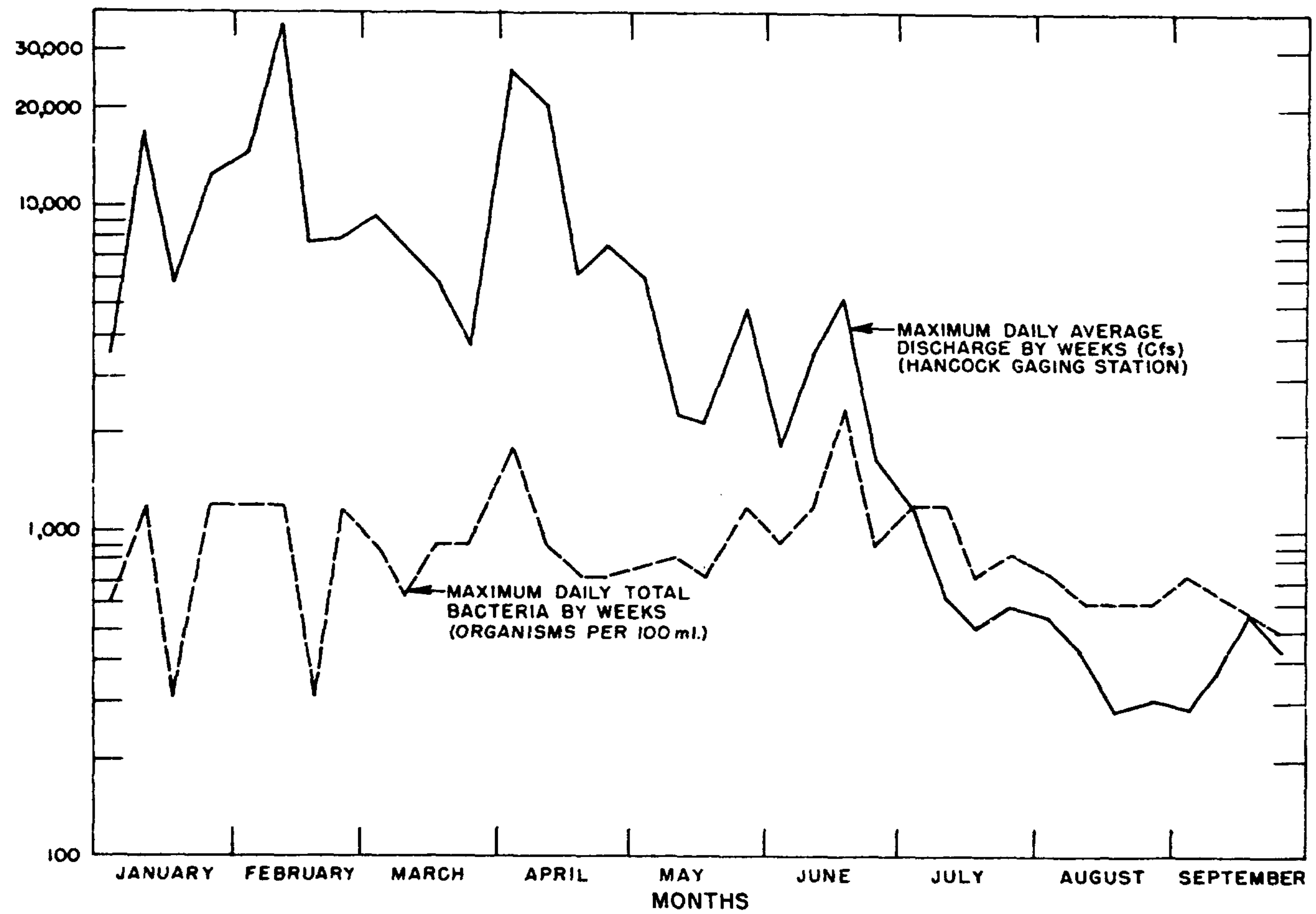
Name of Stream and Station Location	No. of Samples	D.O., ppm			BOD, ppm			Coli./100 ml.			Other		
		Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.
Shenandoah River, W. Va. Below Va. border (4.5 mi.)	6	8.84	9.80	8.20	2.04	2.35	1.50	1,800	7,500	65	Iron & Manganese, ppm 0.75	1.14	0.30
Shenandoah River, W. Va. Above mouth (1 mi.)	7	8.81	9.65	7.65	3.34	6.80	1.70	10,550	32,000	500	Tannin, ppm 0.96	1.15	0.70
Catoctin Cr., Md. Above mouth (3 mi.)	6	9.94	9.30	6.80	1.51	1.60	1.25	12,900	42,000	1,200			
Rock Cr. of Monocacy River Below Gettysburg, Pa. (2 mi.)	6	4.50	6.75	1.50	4.63	6.40	2.60	13,400	61,000	90			
Monocacy River Below Pa. border (13 mi.) Below Gettysburg, Pa. (27 mi.) Below Taneytown, Md. (20 mi.)	6	6.29	9.80	6.90	2.34	4.55	0.70	7,700	24,000	700			
Monocacy River Below Frederick, Md. (7 mi.)	6	5.45	6.30	4.20	2.10	2.55	1.65	40,500	73,000	7,400			
Monocacy River Below Frederick, Md. (18 mi.) Above mouth (2 mi.)	6	7.60	8.60	6.55	1.55	2.80	1.10	4,100	16,000	300			
Potomac River, Main Stem At Paw Paw, W. Va.	7	7.46	8.90	6.60	2.07	4.25	1.25	11,000	70,000	500	Tannin, ppm* 1.45	2.30	0.70
Potomac River, Main Stem At Brunswick, Md.	7	7.39	8.85	5.35	1.84	3.30	1.20	6,450	28,000	130	Tannin, ppm* 0.73	0.80	0.65
Potomac River, Main Stem At Point of Rocks	7	8.21	9.92	7.45	2.26	4.60	0.95	810	4,100	40	Iron & Manganese, ppm 0.49	0.72	0.22
Potomac River, Main Stem At Great Falls	6	7.77	9.40	6.60	2.26	5.20	0.80	225	600	86			

* As tannic acid.



POTOMAC RIVER
HAGERSTOWN WATER PLANT INTAKE, WILLIAMSPORT, MD., 1957
RELATIONSHIP BETWEEN TURBIDITY AND RIVER DISCHARGE

FIGURE 6



POTOMAC RIVER
HAGERSTOWN WATER PLANT INTAKE, WILLIAMSPORT, MD., 1957
RELATIONSHIP BETWEEN TOTAL BACTERIA AND RIVER DISCHARGE

FIGURE 7

Sphaerotilus growths can impair fishing, clog filters at water treatment plants, and crowd out desirable bottom fauna. Also, Sphaerotilus can accumulate in pools to create sludge banks which may become anaerobic.

The South Branch of Conococheague Creek below Mercersburg, Pennsylvania contained dark brown turbid water. The stream in this area is void of bottom life for several miles. It is reported that prior to industrial operations at Mercersburg, the stream provided excellent fishing.

All points observed along the Monocacy River indicated high silt content. Bottom flora was sparse and numerous silt banks or bars were visible.

Opequon Creek, from West Virginia Route 45 to its confluence with the Potomac River, was turbid during the operating hours of a sand washing plant. The plant is in operation approximately 40 hours per week.

Most of the tributaries to the Potomac River carry heavy silt loads after rains. Reports indicate that in addition to the above named creeks, Great Tonoloway and Licking Creeks contribute heavy loads of silt to the Potomac River.

Antietam Creek below Hagerstown, Maryland, was observed to be generally dark in color, contained oily substances, and usually possessed an odor of domestic sewage.

Upon several occasions during the survey, samples collected from the Potomac River at Paw Paw, West Virginia and Hancock, Maryland, exhibited foamy characteristics indicative of waters containing detergents or resin soaps. Water polluted by laundry wastes, tannery wastes, and pulp mill waste exhibit similar characteristics.

Identification of Pollution Sources

According to sampling results at locations where pollution characteristics were observed, it is apparent to what waste source or sources and type of waste the reduced water quality and condition of the stream should be attributed.

The types of wastes involved at locations upstream from those sampling points showing water quality inconsistent with the objectives for domestic and industrial process water are as follows:

Domestic Wastes - Indicated by excessive biochemical oxygen demand, lowered dissolved oxygen content, and large numbers of coliform organisms.

Tannery Wastes - Indicated by excessive biochemical oxygen demand, lowered dissolved oxygen content, and variable tannin concentrations.

Slaughterhouse and Poultry Wastes - Indicated by excessive biochemical oxygen demand, lowered dissolved oxygen content, and large numbers of coliform organisms.

Cannery and Dairy Wastes - Indicated by excessive biochemical oxygen demand and lowered dissolved oxygen content.

Glass-Sand Processing Wastes - Indicated by high turbidity and solids, excessive deposits of silt and clay on the stream bed, and absence of bottom life.

Railroad Yard, Petroleum Depot - Indicated by oil slicks on the surface of stream and oily coating on banks.

Pulp and Paper Wastes - Indicated by excessive biochemical oxygen demand, lowered dissolved oxygen cotent and colored or foamy water.

The sources of wastes and estimated waste loads discharged upstream from the survey sampling stations showing excessive pollution characteristics are shown in Table 14.

DISCUSSION OF RESULTS

WATER QUALITY AND DEGREE OF POLLUTION

The stream sampling data collected during the 1958 survey revealed a wide range in water quality throughout the portions of the Potomac Basin studied. The best quality water existed in streams receiving no municipal or industrial wastes or at locations of sufficient distance or time of stream travel downstream from waste sources that recovery or improvement in quality by natural self-purification processes had taken place.

The suitability of water for water supply purposes was found to be essentially a function of the degree of pollution and rate of waste assimilation in the various streams. The parameters examined, other than coliform group organisms, biochemical oxygen demand, dissolved oxygen, and phenolic compounds (tannin and lignin), were generally within concentration limits suitable for raw water supplies, although it is known that at times of higher flow than encountered during the survey turbidity and solids contents exceed desirable limits for removal of these substances by conventional water treatment methods.

Table 14

Waste Sources and Loads Located Upstream from Sampling Stations
Showing Characteristics Inconsistent with Class C
Water Quality Objectives

Location of Waste Sources	Type Waste	WASTE DISCHARGE Est. % Removed	Est. Q Discharged GPD	Est. Pop. Equiv. Disch.
SOUTH BRANCH				
Petersburg, W. Va.	Domestic	None	100,000	1,000
Moorefield, W. Va.	Domestic	None	105,000	950
Lowengart & Co.	Tannery	45	100,000	2,700
Rockingham Poultry Co.	Poultry	None	135,000	3,350
WARM SPRINGS RUN				
Berkeley Springs	Domestic	None	170,000	700
Aulabaugh Bros., Inc.	Cannery	None	18,000	900
Pennsylvania Sand-Glass	Silt & Clay	None	180,000	-----
CONOCOCHEAGUE CREEK				
Chambersburg, Pa.	Domestic	35	1,500,000	12,000
H. J. Heinz Co.	Canning	85	500,000	3,600
Mercersburg, Pa.	Domestic	75	185,000	600
Lowengart & Co.	Tanning	40	220,000	6,600
OPEQUON CREEK				
Winchester, Va.	Domestic	75	2,530,000	3,600
Middleway, W. Va.	Domestic	35	85,000	445
Inwood, W. Va.	Domestic	None	19,000	360
Musselman Canning Co.	Canning	60	300,000	9,000
Leetown, W. Va.	Domestic	None	33,000	270
Kearneysville, W. Va.	Domestic	None	78,000	630
Martinsburg, W. Va.	Domestic	33	2,500,000	12,000
Blair Limestone Co.	Silt & Clay	Settling	No Record	-----
ANTIETAM CREEK				
Waynesboro, Pa	Domestic	75	1,100,000	245
Hagerstown, Md.	Domestic	83	5,235,000	5,700
Fairchild Aircraft Co.	Domestic	75	165,000	1,870
Fairchild Aircraft Co.	Plating, Chrome Salts	None	465,000	-----
Mellendore Slaughter House	Slaughtering	50	18,000	1,000
Western Maryland RR Co.	Washington, Degreasing	Preventive*	375,000	-----
Funkstown, Md.	Domestic	75	100,000	200
North American Cement Co.	Silt & Clay	None	------	-----
Keedysville, Md.	Domestic	None	47,000	375
MONOCACY RIVER				
Gettysburg, Pa.	Domestic	95	500,000	480
Littlestown, Pa.	Domestic	75	140,000	710
Taneytown, Md.	Domestic	75	200,000	450
E. J. Nusbaum Co.	Canning	None	50,000	2,500
A. W. Feeser Co., Inc.	Canning	40	35,000	1,050
Emmitsburg, Md.	Domestic	33.5	160,000	700
St. Marys College	Domestic	33.5	75,000	400
St. Josephs Academy	Domestic	35	100,000	260
A. W. Feeser Co., Inc. (Silver Run Plant)	Canning	40	35,000	1,050
Westminster, Md.	Domestic	77	580,000	630
Mt. Pleasant Canning Co.	Canning	10	30,000	1,350
Willow Farm Dairy	Dairy	Preventive*	40,000	123
New Windsor, Md.	Domestic	None	80,000	646
Western Maryland Dairy	Dairy	Preventive*	30,000	23
Joseph N. Weller Co.	Canning	None	15,000	750
Union Bridge, Md.	Domestic	35	94,000	490
Tingling Bros. Co.	Slaughter	Preventive*	10,000	1,120
A. W. Feeser Co., Inc. (Keymar Plant)	Canning	None	60,000	3,000
(Union Bridge, Md.) Western Maryland Dairy (Detour Plant)	Dairy	Preventive*	125,000	625
Frederick, Md.	Domestic	-----	2,800,000	24,000
Everedy Co.	Plating, Chrome Salts	Preventive*	150,000	-----
POTOMAC RIVER				
Paw Paw, W. Va.	Domestic	33	43,000	530
Hancock, Md.	Domestic	None	310,000	780
Williamsport, Md.	Domestic	35	65,000	[illegible]
W. D. Byron Co.	Tannery	40	33,000	[illegible]
DuPont Co. (Falling Waters, W. Va.)	Explosives	None	500,000	-----
Shepherdstown, W. Va.	Domestic	None	90,000	2,000
Moore Sand & Gravel Co.	Silt & Clay	Settling	288,000	-----
Harpers Ferry and Bolivar, W. Va.	Domestic	None	30,000	230
Brunswick, Knoxville, and Weverton, Md.	Domestic	50	400,000	4,000
B & O RR	Washington, Degreasing	Screens	1,000	-----

Note: Shenandoah River sources are omitted for lack of sufficient stream quality data.

* Efforts are made to prevent disposal of wastes to watercourse.

For discussion purposes the term "good" or "excellent" quality water implies suitability of water for supply purposes meeting the Class C water quality objectives. The term "polluted" water implies water quality not meeting the Class C objectives, therefore considered unsuited for supply purposes.

The tributary streams appearing of good quality in their entirety are as follows: North Fork of the South Branch, Town Creek, Little Cacapon River, Cacapon River, Sleepy Creek, Licking Creek, and Back Creek. The major portion of Patterson Creek of the North Branch is considered of good quality except for the portion below Fort Ashby, West Virginia, where coliform group organisms (survey average - 5,980 per 100 ml.) exceeded the objective for Class C water as established by the Interstate Commission on the Potomac River Basin (500 - 5,000 coliform organisms per 100 ml).

The South Fork of the South Branch above Moorefield, West Virginia, contained excellent quality water and the South Branch above Petersburg, West Virginia, was of good quality except that sewage bacteria in excess of the objective for Class C water existed a short distance below Franklin, West Virginia. The heaviest polluted area in the South Branch Basin occurred in the South Fork immediately below Moorefield and in the main stem of the South Branch below the mouth of the South Fork. The number of coliform organisms at each location below Moorefield (survey average - 140,800 and 13,300 per 100 ml, respectively) exceeded the Class C water quality objective, and the biochemical oxygen demand and dissolved oxygen concentrations immediately below Moorefield (survey average - BOD - 4.8 ppm and DO - 6.2 ppm) did not meet the objectives for Class C water (average monthly BOD - 2.0 ppm and DO - 6.5 ppm). However, in recognition of these stream conditions the City of Moorefield is constructing a sewage treatment plant and the State Water Resources Commission of West Virginia is studying the needs for additional industrial waste treatment in that area. Recovery to good quality water occurred in the South Branch between Moorefield and Romney, West Virginia. The good condition of the stream below Romney indicated that the degree of waste treatment at this city was sufficiently effective in preserving the quality of the stream water. Concentrations of phenolic compounds (tannin - survey average as tannic acid - 0.65 ppm) in excess of threshold limits for taste and odor in drinking water (Public Health Service recommended maximum phenolic compounds - 0.001 ppm) were found between Moorefield and the mouth of the South Branch.

The upper reach of the Potomac River in the vicinity of Paw Paw, West Virginia, was subject to numbers of coliform organisms (survey average - 11,000 per 100 ml.) in excess of Class C water quality objectives. Concentrations of phenolic compounds (survey average - 1.45 ppm) greater than were found in the lower reaches of the South Branch indicated that the North Branch also contributed concentrations of these compounds in excess of desirable taste and odor threshold limits. Whereas the Potomac River at Paw Paw contained biochemical

oxygen demand (survey average BOD - 2.1 ppm and maximum BOD - 4.25 ppm) in excess of both criteria for Class C water (monthly average BOD - 2.0 ppm and maximum single observed BOD - 4.0 ppm) and the South Branch contributed only a portion of the total, (survey average BOD - 0.70 ppm; survey maximum BOD - 0.95 ppm) the increase in biochemical oxygen demand in excess of the objective is attributed to North Branch sources. The improved condition of the Potomac River above Hancock, Maryland, (survey average coliform organisms - 110 per 100 ml. and BOD - 0.65 ppm) indicated that the river possessed rapid natural self-purification capacity and that good quality tributary water entering the reach between Paw Paw and Hancock aided the improved condition.

Below Hancock, however, the Potomac River was grossly polluted by heavy suspensions of glass-sand wastes from Warm Springs Run (survey observation) resulting in heavy bottom deposits of silt and clay extending at least ten miles below this source.

Warm Springs Run was grossly polluted below Berkeley Springs, West Virginia, (survey average BOD - 3.7 ppm and turbidity 10,500 ppm) by cannery waste, domestic sewage, and glass-sand waste.

Conococheague Creek was critically polluted below Chambersburg, Pennsylvania,(survey average coliform organisms - 35,700 per 100 ml, BOD - 3.25 ppm, and DO - 3.25 ppm) and the west branch of Conococheague Creek below Mercersburg contained heavy concentrations of tannery waste (survey observation). The stream was considerably improved downstream in the vicinity of the Pennsylvania-Maryland state line (survey average coliform organisms - 2,350 per 100 ml, BOD - 1.15 ppm, and DO - 7.70 ppm) although tannin concentrations exceeded the limits for taste and odors in drinking water (survey average tannin 0.85 ppm). Water of suitable quality for domestic and industrial use existed in Conococheague Creek above Williamsport, Maryland, (survey average coliform organisms - 560 per 100 ml, BOD - 1.1 ppm, and DO - 9.0 ppm). The condition of Conococheague Creek below Chambersburg, Pennsylvania, is expected to improve upon completion of a new activated sludge plant at Chambersburg.

The Potomac River at the Hagerstown water supply intake above the mouth of Conococheague Creek contained good quality water (survey average coliform organisms - 650 per 100 ml, BOD - 1.0 ppm, and DO - 8.85 ppm) except for concentrations of tannin (survey average tannin - 0.50 ppm) in excess of taste and odor limits.

The section of Opequon Creek from the Virginia-West Virginia state line to below Martinsburg, West Virginia, was unsuited as a source of water supply according to Class C water quality objectives. Above Martinsburg, Opequon Creek contained coliform organisms (survey average - 24,500 per 100 ml) in excess of the objective. Biochemical oxygen demand and dissolved oxygen concentrations in this section (survey average BOD - 1.15 ppm and DO - 8.2 ppm) were within acceptable limits. Opequon Creek, below the mouth of Tuscarora Creek into

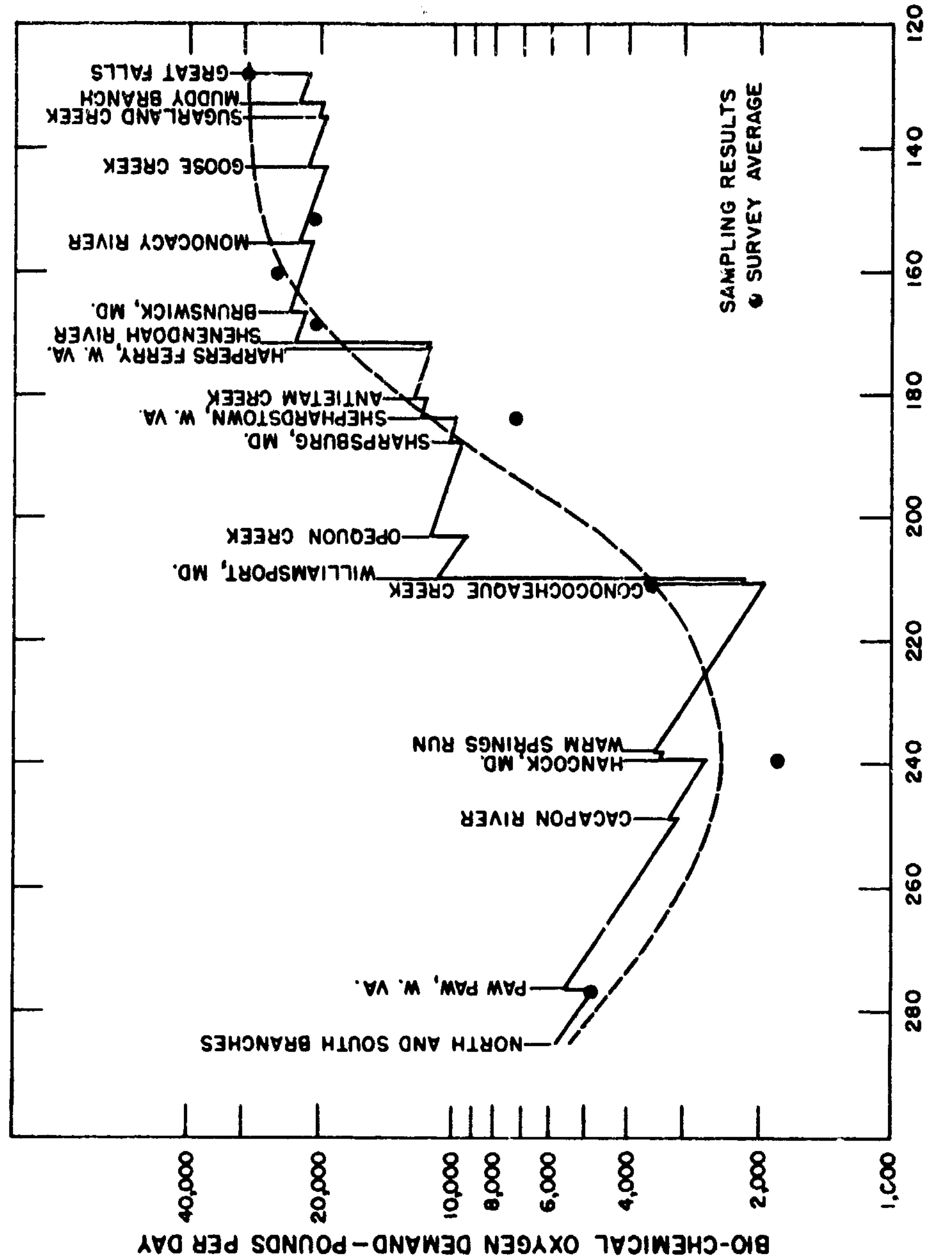
which wastes are discharged by the City of Martinsburg, was characterized by excessive coliform organisms and BOD (survey average coliform organisms - 211,200 per 100 ml and BOD - 5.3 ppm).

The quality of Potomac River water near Shepherdstown, West Virginia, was affected by increases in biochemical oxygen demand (survey maximum BOD - 4.25) originating from Williamsport, Opequon Creek, and Sharpsburg (see Figure 8). Increases in tannin concentrations (survey average tannin - 0.60 ppm) believed to have originated from the tannery at Williamsport and Conococheague Creek were also found in this section of the Potomac River (see Figure 9).

Antietam Creek below Waynesboro, Pennsylvania, contained coliform organisms in excess of the objective for domestic and industrial water (survey average coliform organisms - 9,400 per 100 ml) but in other respects was of suitable quality (survey average BOD - 1.55 ppm and DO - 7.85 ppm). At Funkstown, Maryland, below Hagerstown, Antietam Creek was grossly polluted (survey average coliform organisms - 505,500 per 100 ml, BOD - 4.1 ppm, and minimum DO - 3.9 ppm) by domestic and industrial wastes discharged to the stream in this area. Recovery to relatively good quality water occurred between Funkstown and the mouth of Antietam Creek (survey average coliform organisms - 2,900 per 100 ml, BOD - 1.25 ppm, and DO - 8.80 ppm). Except for plating wastes known to be discharged to the stream in the Hagerstown area, the waters entering the Potomac River from Antietam Creek were essentially unpolluted.

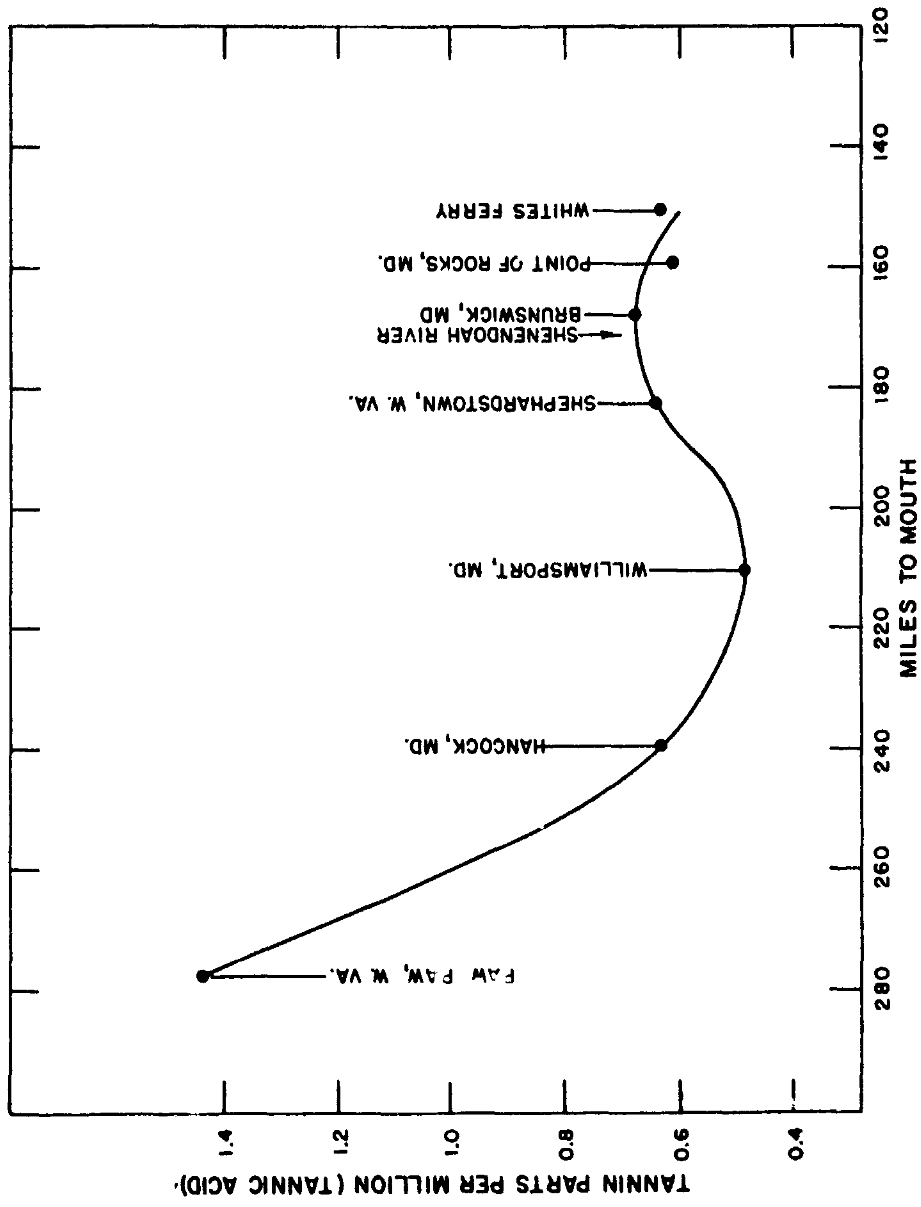
The section of the Shenandoah River from the Virginia-West Virginia border to the Potomac River contained biochemical oxygen demand and tannin concentrations in excess of objectives and recommended limits for these substances (survey average BOD - 3.35 ppm, maximum BOD - 6.8 ppm, and tannin - 0.95 ppm). The numbers of coliform organisms found near the mouth of the Shenandoah River also exceeded the objective (survey average coliform organisms - 10,550 per 100 ml) and were greater in numbers than those found near the Virginia-West Virginia border (survey average 1,810 per 100 ml) indicating significant local pollution from Charles Town, Bolivar, and Harpers Ferry, West Virginia, in addition to sources in Virginia. Dissolved iron and manganese (survey average iron and manganese - 0.75 ppm) in excess of recommended limits for domestic water (total iron and manganese - 0.3 ppm) also occurred in the waters of the Shenandoah River.

The lowered quality of Potomac River water below the mouth of the Shenandoah River reflected the effect of wastes and low quality tributary water entering the Potomac River in that area. Excessive coliform organisms (survey average - 6,450 per 100 ml) and increased biochemical oxygen demand (survey average - 2.2 ppm, maximum - 4.60 ppm) appearing to have originated mainly from Shepherdstown, Harpers Ferry, the Shenandoah River and Brunswick (see Figure 8) characterized the reach of the Potomac River below the mouth of the Shenandoah River. Dissolved iron and manganese (survey average - 0.46 ppm) and tannin concentrations (survey average - 0.75 ppm) in excess of recommended limits also existed.



POTOMAC RIVER
BIO-CHEMICAL OXYGEN DEMAND DISTRIBUTION AND WASTE LOAD PATTERN
SEPTEMBER-OCTOBER 1958

FIGURE 8



POTOMAC RIVER
AVERAGE TANNIN-LIGNIN CONTENT
PAW PAW, W. VA. TO GREAT FALLS
SEPTEMBER-OCTOBER 1958

FIGURE 9

The Monocacy River was affected by sewage and other forms of pollution throughout most of its length. Rock Creek of the Monocacy River was grossly polluted below Gettysburg, Pennsylvania. Sewage bacteria (survey average coliform organisms - 13,400 per 100 ml), concentrations of biochemical oxygen demand (survey average - 4.56 ppm), and dissolved oxygen (survey average - 4.50 ppm, minimum 1.50 ppm) were inconsistent with Class C water quality objectives. The main stem of the Monocacy River below the mouth of Double Pipe Creek contained adequate dissolved oxygen (survey average - 8.3 ppm); however, the numbers of coliform organisms (survey average - 7,700 per 100 ml) and concentrations of biochemical oxygen demand (survey average - 2.35 ppm) in these waters were in excess of the respective objectives for these components. Below Frederick, Maryland, the Monocacy River contained extremely high numbers of coliform organisms (survey average - 40,400 per 100 ml), and the biochemical oxygen demand (survey average - 2.1 ppm) and dissolved oxygen concentrations (survey average - 5.45 ppm, minimum 4.20 ppm) did not meet the objectives for Class C water quality. The waters entering the Potomac River from the Monocacy River had improved in quality (survey average coliform organisms - 4,100 per 100 ml, BOD - 1.55 ppm, DO - 7.60 ppm) to such extent that no significant effect on the quality of Potomac River water from this particular source was detectable at points downstream.

The additive effect of residual pollutants from many upstream sources appeared to sustain and even increase the level of undesirable substances in the waters of the Potomac River between Whites Ferry and Great Falls. Tannin concentrations in excess of taste and odor threshold limits persisted in this section (survey average tannin - 0.75 ppm) and the total of dissolved iron and manganese (survey average 1.88 ppm) was considerably higher than the recommended level for these materials in water supplies.

According to stream data collected during the survey period by the Water Division of the District of Columbia, the Potomac River at Great Falls contained significantly greater concentrations of biochemical oxygen demand (survey average - 2.25 ppm, maximum - 5.2 ppm) than were found upstream at Whites Ferry (survey average - 1.65 ppm, maximum - 2.35 ppm). The increase in biochemical oxygen demand was of such magnitude that a lowering of dissolved oxygen concentration had occurred between Whites Ferry and Great Falls (survey average DO - 8.10 and 7.85 ppm, respectively) (see Figure 10). The significance of the quantity of BOD contained in the Potomac River at Great Falls lies in its important relationship to the stream capacity objective for the Washington Metropolitan Area as established by the Interstate Commission on the Potomac River Basin and to the apparent indication that either secondary stages (nitrification) of biochemical oxygen demand were in progress or that an acceleration of carbonaceous BOD satisfaction (first stage) was taking place downstream from Whites Ferry. Based upon river flows and BOD data at Great Falls, the Potomac River carried a maximum load of approximately 45,000 pounds of BOD and an average of 28,000 pounds of BOD per day, respectively, during the survey. These values represent a large percentage (23

and 37 per cent, respectively) of the tentative stream capacity objective (120,000 pounds BOD per day) estimated for the Washington Metropolitan Area.

An increase of about 8,000 pounds of BOD per day (equivalent to a population of 48,000 persons) occurred between Whites Ferry and Great Falls. There are not sufficient sources of wastes within this reach to account for the magnitude of increase found (see Figure 8).

Figure 8 summarizes the distribution of biochemical oxygen demand (5-day 20°C) and pattern of waste loads (from sampling and waste load inventory) introduced to the Potomac River between the confluence of the North and South Branches and Great Falls. The North Branch contributed approximately 4,850 pounds of BOD per day (P.E. 29,000 persons) or nearly 90 per cent of the total BOD existing in this upper section of the Potomac River. Figure 11 shows the stream sections which exhibited pollution characteristics.

WATER QUALITY AND SANITATION RELATIVE TO POSSIBLE RESERVOIR SITES

Preliminary investigations by the Corps of Engineers reveal many possible dam sites in the Upper Potomac Basin. For discussion purposes, twenty-five of the more favorable sites between Cumberland, Maryland, and Harpers Ferry, West Virginia, are chosen. Figure 12 shows the approximate locations of these twenty-five sites.

It is noted that possible dam sites exist both upstream and downstream from various communities and municipalities in the Potomac Basin, and that in several instances entire communities are located within reservoir areas. Generally, of course, reservoirs for water supply purposes are best located upstream from populated areas; however, it is realized that limited drainage area and storage capacity at such locations reduces the effectiveness of water control on a basin-wide scale. The establishment of sites downstream from populated areas invariably involves sources of water pollution which must either be tolerated or corrected. In some cases where upstream communities appear relatively unimportant as sources of pollution at the present time, it should be pointed out that these communities may grow with the water resources development in the area and thereby become significant as contributors to reduced water quality.

As pertains to the relocation of communities, considerations should be given to water supply and to sewage collection and treatment depending upon populations and proximity of the new location with respect to the reservoir.

In cases where recreational use of a reservoir is anticipated and sources of pollution exist, adequate measures for the protection of the health of such users should be considered.

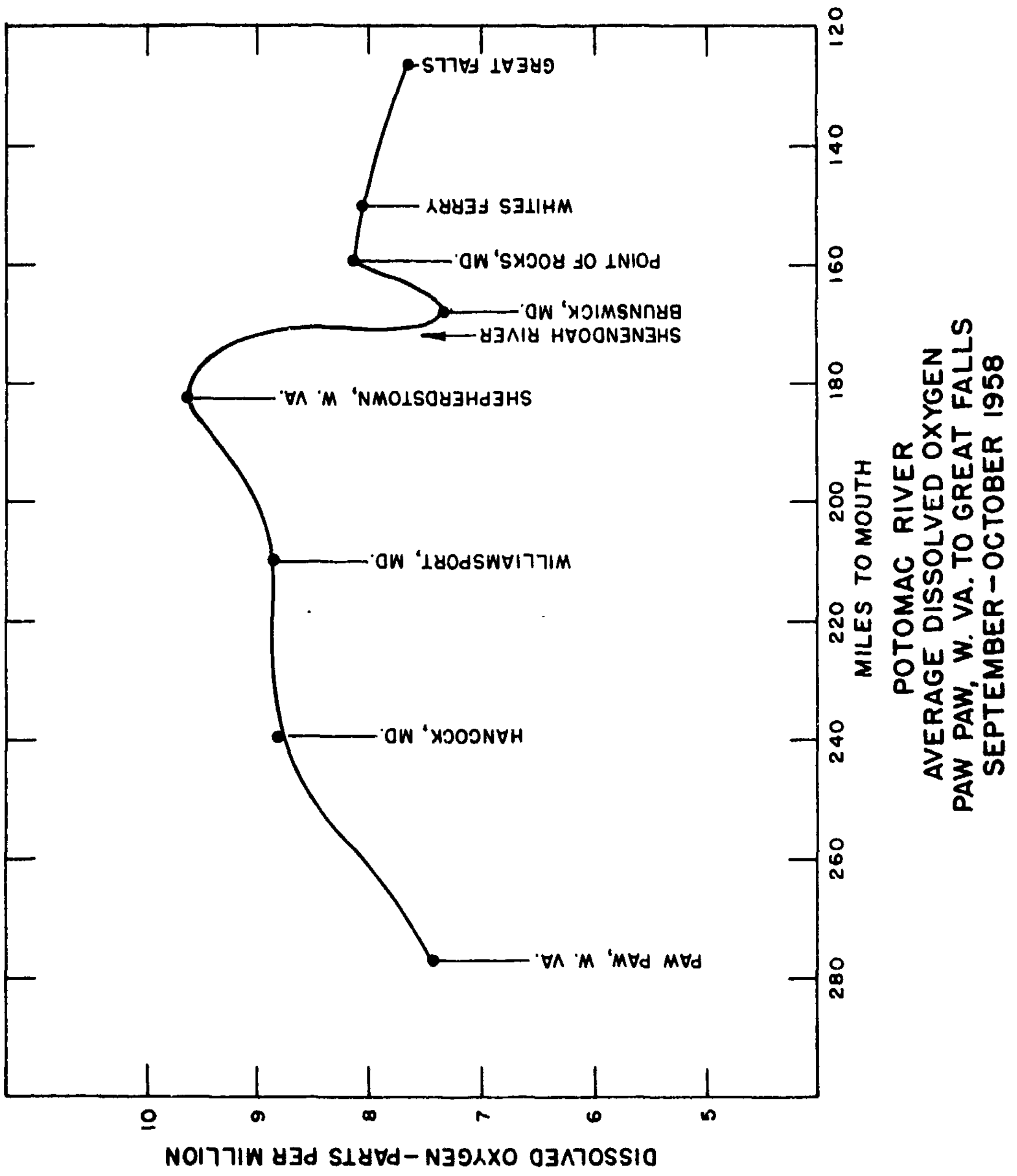
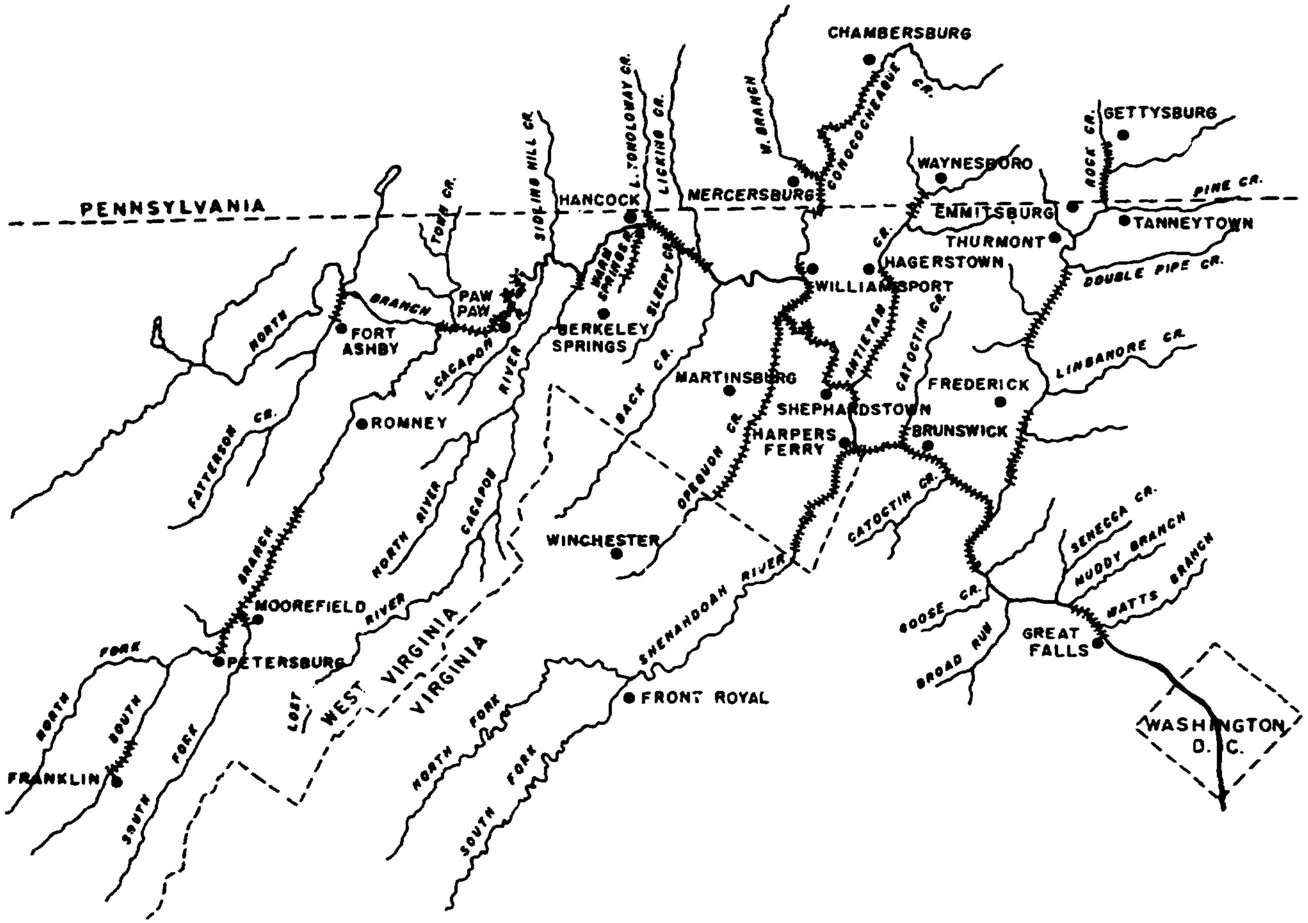

POTOMAC RIVER
AVERAGE DISSOLVED OXYGEN
PAW PAW, W. VA. TO GREAT FALLS
SEPTEMBER-OCTOBER 1958
MILES TO MOUTH
DISSOLVED OXYGEN-PARTS PER MILLION
GREAT FALLS
WHITES FERRY
POINT OF ROCKS, MD.
BRUNSWICK, MD.
SHENENDOAH RIVER
SHEPHERDSTOWN, W. VA.
WILLIAMSPORT, MD.
HANCOCK, MD.
PAW PAW, W. VA.
120
140
160
180
200
220
240
260
280
10
9
8
7
6
5

FIGURE 10



POTOMAC RIVER BASIN
STREAM SECTIONS EXHIBITING POLLUTION CHARACTERISTICS
(1958 FIELD SURVEY)

FIGURE 11

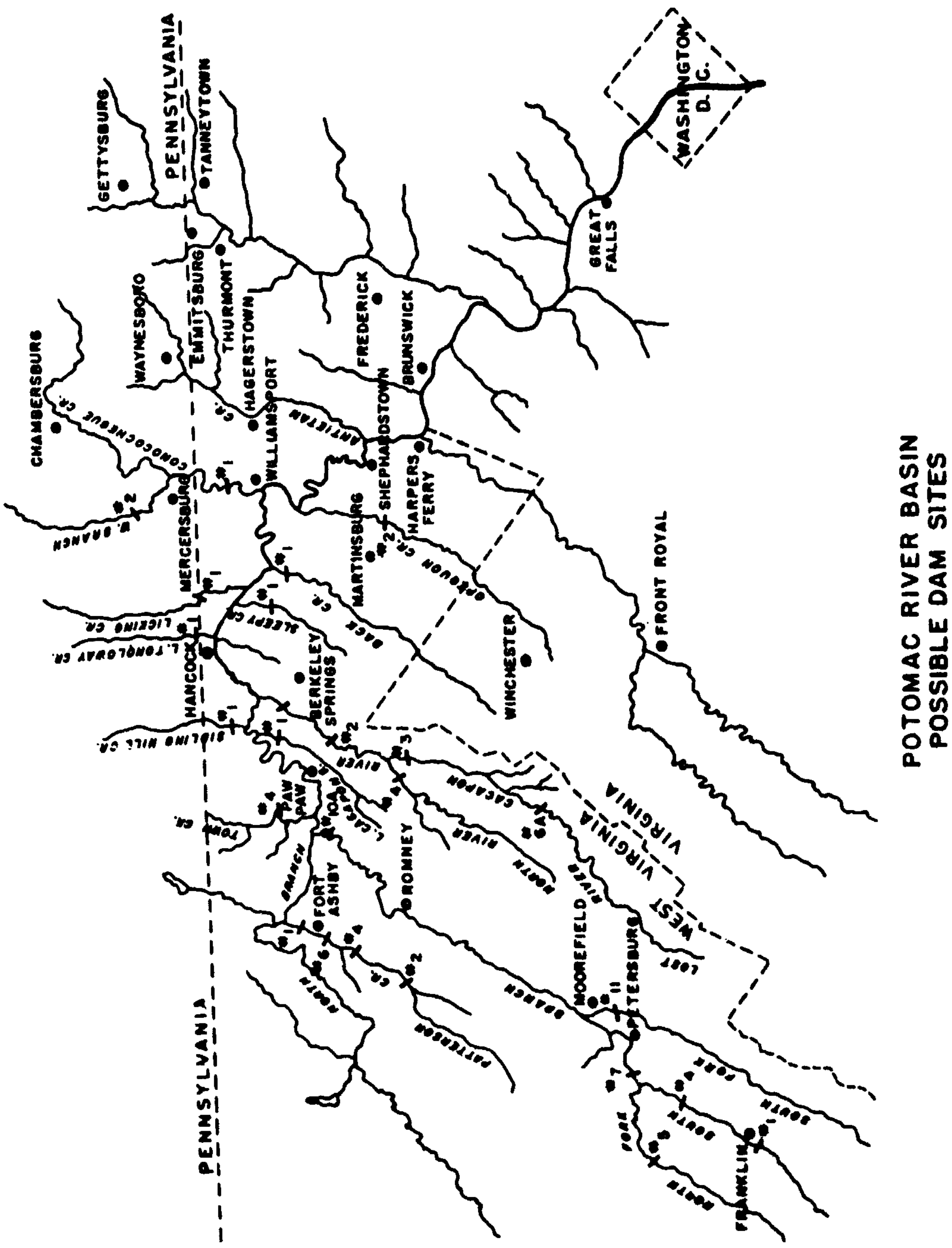

POTOMAC RIVER BASIN
POSSIBLE DAM SITES
PENNSYLVANIA
WEST VIRGINIA
VIRGINIA
WASHINGTON D.C.
GREAT FALLS
GETTYSBURG
TANNEYTOWN
EMMITSBURG
THURMONT
WAYNESBORO
CHAMBERSBURG
HAGERSTOWN
FREDERICK
BRUNSWICK
WILLIAMSPORT
SHEPHERDSTOWN
HARPERS FERRY
MARTINSBURG
MERCERSBURG
HANCOCK
BERKELEY SPRINGS
WINCHESTER
FRONT ROYAL
PAW PAW
FORT ASHBY
ROMNEY
MOOREFIELD
PETERSBURG
FRANKLIN
CONOCOCHEAGUE CR.
ANTIETAM
OPEQUON CR.
BACK CR.
SLEEPY CR.
LICKING CR.
L. TONOLOWAY CR.
SIDELING HILL CR.
CACAPON RIVER
NORTH RIVER
LOST RIVER
PATTERSON CR.
SOUTH BRANCH
SOUTH FORK
NORTH FORK

FIGURE 12

Reservoirs located downstream from population centers can operate to advantage with respect to water quality if managed with local interests in mind. For instance, waters contaminated by sewage, when impounded undergo certain improvements by virtue of time in storage. This sometimes takes place at the expense of dissolved oxygen losses in deep water areas, but considerable reductions in sewage bacteria and sewage organic matter can result. For this reason, it is possible in some instances to restrict certain areas to specific uses depending upon local and state water quality requirements. Water discharged from reservoirs, although sometimes lower in dissolved oxygen and altered in temperature, usually has undergone enough improvement in bacterial and organic quality as to be suitable for downstream use. Care should be exercised in the initial establishment of a reservoir which is to be used as a source of water supply, to remove as much vegetation as possible to prevent taste and odor problems from arising after flooding.

The quality of impounded water can diminish in water supply value over a period of time depending upon location with respect to certain agricultural activities or to the existence of inflowing waters containing appreciable quantities of certain industrial and municipal waste decomposition products and/or inorganic waste constituents. For example, long-time accumulation of nutrient substances, nitrogen, and phosphorus, contained in run-off water from fertilized land or originating from industrial and municipal waste discharges will induce over-productions of aquatic growths. Excessive growths of aquatic vegetation along shallow shore areas are unsightly and promote increased mosquito production. Excessive algae production, also associated with highly nutritious waters, is aesthetically unattractive, imparts disagreeable tastes and odors to the water and impairs satisfactory treatment of water for domestic and industrial uses.

Insecticides and fungicides sprayed in areas adjacent to reservoirs or upstream watersheds can accumulate in the impounded water through adherence to silt particles. These substances can cause latent toxicity to biological activity for several years. A build-up of toxic substances can hinder the normal photosynthetic production of oxygen by interfering with the algal metabolism in water and can be detrimental to the health of the populations using the source for water supply.

The comments on individual dam sites, as made below, are based upon water quality data collected to date, and upon results of studies made on water uses, waste loads, and disposal practices as presently exist in the portions of the Potomac River Basin under investigation. Also, the statements made on water quality are based upon generally accepted water quality criteria. Unless otherwise stated, the term "good quality" indicates that the location referred to is a good source of water supply for most uses and meets recommended requirements for dissolved oxygen, biochemical oxygen demand, most probable

number of coliform organisms, hydrogen-ion concentration (pH), total alkalinity, hardness, turbidity, total solids, iron and manganese, and phenolic compounds.

Although not specifically stated in the discussions of individual dam sites to follow, it is understood that all water storage facilities located in the upper Potomac River Basin which provide low flow augmentation would be useful to downstream users and would be especially useful in satisfying demands for municipal water supply at Washington, D. C., during drought seasons.

PATTERSON CREEK

Sites No. 2 and 4 - These sites are located in areas of good quality water and are equal in suitability for water supply provided the community relocation required for site #4 includes provisions for sewage collection and treatment or some means of preventing domestic wastes from entering the reservoir. Approximately 1,700 persons residing in communities along Patterson Creek would be benefited by these sites.

Site No. 6 - The quality of water at this site is similar to that at Sites No. 2 and 4, but is potentially subject to upstream pollution originating at Burlington, West Virginia. A hazard to the health of recreational users could occur in at least the headwater areas of this reservoir. The community relocation required for use of this site should include provisions for sewage collection and treatment or some means of preventing wastes from entering the reservoir. Approximately 1,300 persons residing in communities along Patterson Creek would be benefited by this site.

Site No. 1 - The water at this site contains excessive numbers of sewage bacteria but is otherwise of good quality for water supply purposes. Since Fort Ashby, West Virginia, appears to be the source of this sewage pollution and its relocation would be required, the site would be suitable for water supply provided the relocation included collection and treatment of sewage or some means of preventing wastes from entering the reservoir. Approximately 1,150 persons residing in communities along Patterson Creek would be benefited by this site.

SOUTH BRANCH

North Fork

Site No. 5 - This site would provide an excellent source of water for downstream use. Water is of good quality and no potential sources of pollution exist upstream of the site. Approximately 6,500 persons reside in downstream communities and of these about 5,000 now supplied with water from the South Branch would benefit directly by this supply.

South Fork (Moorefield River)

Site No. 11 - This site would provide an excellent source of water for downstream use. The water is of good quality and the site is distant enough downstream from the small community at Brandywine, that essentially no potential source of pollution exists. The supply would be of benefit to industrial uses at Moorefield and to approximately 7,000 persons now served by surface water supplies downstream of this site. Significant pollution abatement benefits may also be obtained by low flow augmentation from this source.

Main Stem of South Branch

Site No. 1 - Water at this site is of good quality and no significant source of pollution exists upstream. Approximately 7,000 persons reside in communities downstream of this site and of these about 5,500 who are presently supplied by municipal facilities would benefit by this supply.

Site No. 4 - The quality of water at this site is affected by sewage bacteria from Franklin, West Virginia. Restrictions on recreational use of the reservoir or treatment of sewage at its source should be considered. The water released from this reservoir, however, should be of suitable quality for downstream use. Approximately 6,500 persons reside in downstream communities and of these about 5,000 who are now supplied by water from the South Branch would benefit directly by this supply.

Site No. 7 - Water at this site is of good quality and the site is distant enough from the sewage discharge at Franklin, West Virginia, that it is relatively unaffected by sewage bacteria. The sewage discharge at Franklin is, however, a potential source of contamination and conceivably could affect the quality of water in the headwater area of the reservoir. Approximately 6,500 persons reside in downstream communities and of these about 5,000 who are now supplied with water from the South Branch could benefit directly by this supply.

Site No. 10A - The water at this site contains quantities of phenolic compounds (tannery wastes) in excess of the limits recommended for taste and odor control. The reservoir area is also subject to residual sewage pollution from Moorefield and to treated sewage effluents from Romney, the latter amounting to a population equivalent of approximately 600 persons. Restrictions on recreational uses in headwater areas of the reservoir should be considered and the use of water for domestic purposes would require special treatment for improvement in potability. This supply would not benefit existing communities along the South Branch but would benefit water users downstream along the Potomac River.

TOWN CREEK

Site No. 4 - Although no water quality data are available on this creek, the site appears to be suitable as a source of water supply. No significant population centers or potential sources of pollution exist in this area. The site would provide benefits to community water supplies downstream along the Potomac River.

LITTLE CACAPON CREEK

Site No. 1 - No water quality data are available on this creek; however, the site appears to be suitable as a source of water supply. No significant population centers or potential sources of pollution exist in this area. The site would provide benefits to community water supplies downstream along the Potomac River.

SIDELING HILL CREEK

Site No. 1 - No water quality data are available on this creek; however, the site appears to be suitable as a source of water supply. No significant population centers or potential pollution sources exist in this area. The site would provide benefits to community water supplies downstream along the Potomac River.

CACAPON RIVER

Lost River

Site No. 6A - Water of good quality exists in the region of this site. There is only a slight possibility of sewage contamination from Lost River State Park where the sewage effluent from partially treated wastes contains an estimated maximum population equivalent of approximately 400 persons. Area restrictions for recreational use in the reservoir or some means of reducing waste loads at the State Park should be considered.

The relocation of the community of Baker, West Virginia, should include provisions for water supply and for sewage collection and treatment or some means of preventing the discharge of wastes to the reservoir. There would be no significant water supply benefits within the Cacapon Basin; however, indirect benefits to community water supplies along the Potomac River would be derived.

North River

Site No. 4 - Water at this site is of good quality and no significant potential source of pollution exists upstream. In event that the community of North River Mill is relocated, provisions for the elimination of waste disposal to the reservoir should be considered. No significant water supply benefits could be obtained along the Cacapon River below this site; however, indirect benefits to community water supplies downstream along the Potomac River would be derived.

Main Stem Cacapon River

Site No's 1, 2, and 3 - Good quality water exists in the region of these sites and no significant potential sources of pollution are located upstream. In event that the communities lying within respective site areas are to be relocated, provisions for the elimination of waste disposal to the reservoir should be considered. No significant water supply benefits could be obtained below these sites; however, indirect benefits to community water supplies downstream along the Potomac River would be derived.

TONOLOWAY CREEK

Site No. 1 - No water quality data are available for this creek; however, the site appears to be suitable as a source of water supply. No significant population centers or potential pollution sources exist in this area. The site would provide benefits to community water supplies downstream along the Potomac River.

SLEEPY CREEK

Site No. 1 - Water of good quality exists in the region of this site. No significant centers of population or potential sources of pollution exist upstream. The site would provide benefits to community water supplies downstream along the Potomac River.

LICKING CREEK

Site No. 1 - No water quality data are available on this creek; however, the site appears to be suitable as a source of water

supply. No siginficant population centers or potential sources of pollution exist in this area. The site would provide benefits to community water supplies downstream along the Potomac River.

BACK CREEK

Site No. 1 - Water at this site is of good quality but subject potentially to sewage discharges from the community of Hedgesville. Restrictions on recreational use in the headwaters of the reservoir or a means of reducing upstream pollution should be considered. In event that the community of Tomahawk, West Virginia, be relocated, provisions for the elimination of waste disposal to the reservoir should be considered. Since the community of Shanghai, West Virginia, would be located on the edge of the reservoir area, provisions for the prevention of waste discharges to the reservoir should be made. This site would provide community water supply benefits downstream along the Potomac River.

CONOCOCHEAGUE CREEK

West Branch

Site No. 2 - This site appears to be suitable as a source of water supply. No significant population centers or potential pollution sources exist in upstream areas. Approximately 3,000 persons residing in downstream communities and one large industry would benefit by this supply. The site would offer pollution abatement benefits by low flow augmentation at the junction of the main stem of Conococheague Creek and points downstream.

Main Stem of Conococheague Creek

Site No. 1 - The water at this site is subject to contamination by sewage bacteria and contains concentrations of phenolic compounds in excess of limits usually required for taste and odor control. The municipal and industrial wastes discharged at upstream points are of such magnitude that lowered dissolved oxygen conditions could also exist in the reservoir. Restrictions in recreational use of the reservoir for the protection of health should be considered. The site would benefit downstream water supplies now serving approximately 2,500 persons and several industries. Communities located downstream along the Potomac River would also be benefited by this supply. Benefits to pollution abatement by low flow augmentation could accrue downstream of this site.

OPEQUON CREEK

Site No. 2 - This site is subject to excessive sewage bacterial pollution from upstream sources and the concentrations of mineral

salts contained in these waters are of such magnitude that treatment for domestic purposes should include provisions for hardness reduction. Restrictions on recreational use of certain areas of the reservoir for the protection of public health should be considered. The site would benefit downstream water supplies now serving over 18,000 persons and several industries. Significant pollution abatement benefits by low flow augmentation could accrue at downstream locations along Opequon Creek. The site would also provide water supply benefits downstream along the Potomac River.

PART III

APPENDIX I

DOMESTIC AND INDUSTRIAL WATER SUPPLY DATA

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
North Branch Potomac	158					
Savage River	54,158				None	None
Frostburg, Md.		8,200	500,000	500,000		
Westernport, Md.		4,200		500,000		
Piedmont, W. Va.		2,700		325,000		
Luke, Md.		980		120,000		
Georges Creek	51,158					
Consolidation Coal Co.		60		5,000		500,000
Borden Shaft, Md.		192		5,000		500,000
Midland, Md.		1,060		135,000		
Lonaconing, Md.		2,750		340,000		
Barton, Md.		695		87,000		
New Creek	46,158					
Keyser, W. Va.		7,000		500,000		
Royal Dairy						35,000
Wills Creek	22,158					
Hyndman, Pa.		1,350		100,000		
Wellersburg, Pa.		369	46,000			
Cumberland Coal Co.		200		5,000		
Cumberland Cement Co.						288,000
Evitts Creek	17,158					
Penn. (Available)		15,000		5,500,000		
Cumberland, Md.		41,028		10,100,000		
Pittsburgh Plate Glass Co.		3,000		75,000		2,000,000
Union Tanning Co.						119,000
Cumberland Laundry Co.						25,000
N. & G. Taylor Co.						100,000
Ridgely, W. Va.		1,972		75,000		

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
Patterson Creek	9,158				None	None
Burlington, W. Va.		400	50,000			
Fort Ashby, W. Va.		800	100,000			
Patterson Creek, W. Va.		350	44,000			
Main Stem	87-0,158					
Davis Coal Co.						500,000
Bayard, W. Va.		589	74,000			
Fairfax Coal Co.						800,000
Kitzmiller, Md.		652	80,000			
W. Va. Pulp and Paper Co.						40,000,000
Mason Dairy, Md.					35,000	
Celanese Corporation						40,000,000
Kelley Springfield Tire Co.						12,000,000
Koppers Co., W. Va.		135	3,000			
South Branch Potomac						
North Fork	73,158	None			None	None
South Fork	57,158					
Moorefield, W. Va.		1,500		165,000		
Rockingham Poultry Co.		125		3,000		135,000
Loewengart Tanning Co.					2,000	100,000
Main Stem South Branch	85-0,158				None	None
Franklin, W. Va.		600	50,000			
Petersburg, W. Va.		2,000		200,000		
Romney, W. Va.		2,500		150,000		
School for Deaf		400		40,000		

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
Cacapon River	121					
Lost River State Park		780	20,000			
Little Tonoloway Creek	112				None	None
Hancock, Md.		1,000		400,000		
Warm Springs Run	111					
Berkeley Springs, W. Va.		750	185,000			
Aulabaugh Bros. Co.					18,000	
Penn. Sand-Glass Co.		225	5,000			180,000
Sleepy Creek	106	None			None	None
Licking Creek	104	None			None	None
Back Creek	99				None	None
Jones Springs, W. Va.		150	18,000			
Hedgesville, W. Va.		420	52,000			
Conococheague Creek	84					
Chambersburg, Pa.		18,500		2,000,000		
H. J. Heinz Co.						500,000
Path Valley Esso					25,000	
Mercersburg, Pa.		2,500		210,000		
Lowengart Tanning Co.					215,000	5,000
Greencastle, Pa.		2,800	478,000			
Greencastle Packing Co.					12,000	
Kemps Mill, Md.		100	3,000			
W. D. Byron Co.					160,000	80,000

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
Opequon Creek	75					
Clearbrook, Va.		200	25,000			
Clearbrook Woolen Co.						65,000
Middleway, W. Va.		760	95,000			
Gerrardstown, W. Va.		250	31,000			
Inwood, W. Va.		400	21,000			
Musselman Canning Co.					300,000	
Leetown, W. Va.		300	37,000			
Kearneysville, W. Va.		700	87,000			
Martinsburg, W. Va.		18,000	2,500,000			
National Fruit Co.					380,000	
Interwoven Co.					120,000	
Standard Lime and Stone Co.		600	15,000		140,000	
Blair Limestone Co.					125,000	
Antietam Creek	53					
Fayetteville, Pa.		3,000		65,000		
Waynesboro, Pa.		9,800		1,900,000		
Scotland Orphanage, Pa.		850		100,000		
S. G. Dixon TB Hospital, Pa.		1,700	170,000	170,000		
E. U. B. Orphanage, Pa.		220	13,000			
Camp Ritchie, Md.		1,600	110,000	110,000		
Smithsburg, Md.		770	96,000			
North American Cement Co., Md.						18,600,000
Hagerstown, Md.		15,500		2,000,000		
Maryland State Penitentiary		75	9,000			
Maryland State Reformatory		400	50,000			
Boonesboro, Md.		1,500	50,000			
Keedysville, Md.		417	52,000			
Shenandoah River	44					
North Fork	54.5,44					
Broadway, Va.		600		144,000		
Shen-Valley Packers						200,000

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
North Fork (Continued)	54.5,44					
Timberville, Va.		271		33,000		
Rockingham Poultry Co-op.						545,000
Valley Housing Corp., Va.		300		37,000		
New Market, Va.		1,000		125,000		
Mount Jackson, Va.		800		100,000		
Edinburg, Va.		533		67,000		
Woodstock, Va.		2,150		270,000		
Strasburg, Va.		2,000		250,000		
Winchester, Va.		16,000		2,810,000		
South Fork	54.5,44					
Waynesboro, Va.		14,800	1,410,000			
E. I. du Pont de Nemours					11,155,000	1,725,000
Crompton-Shenandoah Co.						2,213,000
Staunton, Va.		25,000		2,000,000		
Verona Sanitary District		1,650		200,000		
American Safety Razor Co.		1,200		144,000		
Western State Hospital		1,500	143,000			
Woodrow Wilson School		4,500	112,000			
Skyland-Swannanoa, Va.		250	31,000			
Greenville State Welfare		150	19,000			
Harrisonburg, Va.		11,000		1,350,000		
Dayton, Va.		1,120	140,000			
Bridgewater, Va.		1,537	190,000			
South River Sanitary Dist.		3,500		450,000		
Elkton, Va.		1,640	205,000			
Merck and Co.					6,735,000	
Shenandoah, Va.		2,000		790,000		
Stanley, Va.		399	50,000			
Luray, Va.		3,300		273,000		
Virginia Oak Tannery						280,000

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
South Fork (Continued)	54.5,44					
Stauffer Chem. Co.		45	11,000		25,000	
Front Royal, Va.		9,000		861,000		
American Viscose Corp.		2,200		55,000		4,620,000
Old Virginia Packing Co.						
Allied Chemical and Dye						
Beef Cattle Research		50	12,000			
Viscose City, Va.		400	50,000			
Main Stem Shenandoah	54.5-0,44					
Berryville, Va.		1,690		210,000		
Charles Town, W. Va.		4,500	475,000			
Halltown, W. Va.		300	38,000			
Valley Paper Board Co.		160	4,000		2,225,000	
Michigan Limestone, W. Va.						530,000
Blair Limestone, W. Va.					720,000	
Catoctin Creek, Md.	35				None	None
Meyersville, Md.		250	31,000			
Middletown, Md.		936	115,000			
Burkettsville, Md.		190	23,000			
Catoctin Creek, Va.	33					
Purcellville, Va.		945	118,000			
J. Lynn Cornwell Packing					110,000	
Waterford, Va.		247	30,000			
Lovettsville, Va.		341	43,000			
Tuscarora Creek	28	None			None	None
Monocacy River	26					
Mont Alto, Pa.		1,100	70,000			
Gettysburg, Pa.		8,500		560,000		
Littlestown, Pa.		3,000	150,000			

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
Monocacy River (Continued)	26					
Fairfield, Pa.		428		10,000		
Funkhouser Co., Pa.						108,000
Knouse Food Corp., Pa.						100,000
B. H. Shriver Co., Pa.						83,000
Emmitsburg, Md.		1,300		200,000		
St. Marys College		600	75,000			
St. Josephs Academy		400	100,000			
A. W. Feeser Co. Inc., Md.					35,000	
Taneytown, Md.		1,800	200,000			
Cambridge Rubber Co.					48,000	
Essig Packing Co.					12,000	
E. J. Nusbaum Co.					50,000	
A. W. Feeser Co., Inc.					35,000	
Westminster, Md.		7,380		920,000		
Mount Pleasant Canning Co.					30,000	
Willow Farm Dairy Co.					40,000	
New Windsor, Md.		707	88,000			
Western Maryland Dairy					30,000	
Farmers' Cooperative					15,000	
Joseph H. Weller Co., Md.					15,000	
Union Bridge, Md.		840		105,000		
Yingling Bros. Co.					10,000	
A. W. Feeser Co., Md.					60,000	
George W. Magin Co., Md.					20,000	
Western Maryland Dairy						125,000
Thurmont, Md.		2,500	500,000			
Thurmont Rendering Co.					-	-
Howard Lotte & Co.					18,000	
Fraley's Meats, Md.					9,000	
Maryland TB Sanitarium		600	88,000			
Woodsboro, Md.		427	53,000			
Castle Cheese Co., Md.					1,000	

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
Monocacy River (Continued	26					
Walkersville, Md.		761	95,000			
Western Maryland Dairy					36,000	
Camp Detrick, Md.		500		62,000		
Frederick, Md.		19,990		2,800,000		
Everedy Co.						150,000
Mount Airy, Md.		-				
Western Maryland Dairy					11,000	
George McComas & Cc., Md.					24,000	
Goose Creek	15				None	None
Middleburg, Va.		663	83,000			
Leesburg, Va.		2,050	255,000			
Goose Creek Country Club, Va		300	8,000			
Foxcraft School, Va.		195	5,000			
Seneca Creek	8	None			None	None
Sugarland Creek	7				None	None
Herndon, Va.		1,210	146,000			
Muddy Branch	5				None	None
Gaithersburg, Md.		4,000		500,000		
Potomac River	158-0					
Paw Paw, W. Va.		834	45,000			
Hancock, Md.		(Emergency Only)				
Williamsport, Md.		2,000		130,000		
Hagerstown, Md.		25,500		3,255,000		
Western Maryland RR						375,000
Mullendore Slaughtering						18,000
Fairchild Air Craft Co.		7,500		165,000		465,000
Funkstown, Md.		880		110,000		
Du Pont, Falling Waters		419		10,000		500,000

Water Supply Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD Ground	Domestic GPD Surface	Industrial GPD Ground	Industrial GPD Surface
Potomac River (Continued)	158-0					
Sharpsburg, Md.		866		110,000		
Shephardstown, W. Va.		2,000		90,000		
Meere Sand and Gravel Co.						288,000
Harpers Ferry and Bolivar, W. Va.		2,000	76,000			
Brunswick, Knoxville and Wevertown, Md.		4,500	500,000			
Baltimore and Ohio RR					1,000	
Great Falls Park, Va.		3,000		375,000		

PART III

APPENDIX II

DOMESTIC AND INDUSTRIAL WASTE DATA

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
North Branch Potomac								
Savage River	54,158	None				None		
Georges Creek	51,158							
Frostburg, Md.		5,000	620,000	75	1,250			
Borden Shaft, Md.		192	5,000	None	192	500,000	-	Fines, Silt
Consolidation Coal Co.		60	1,500	None	60	500,000	-	Fines, Silt
Midland, Md.		620	75,000	None	620			
Lonaconning, Md.		1,880	235,000	75	470			
Barton, Md.		480	95,000	None	480			
New Creek	46,158	None				None		
Wills Creek	22,158							
Hyndman, Pa.		1,320	100,000	None	1,320			
Wellersburg, Pa.		330	41,000	None	330			
Cumberland Coal Co.		200	5,000	None	200	500,000	-	Fines, Silt
Cumberland Cement Co.						288,000	Lagoons	Silt
Evitts Creek	17,158	None				None		
Patterson Creek	9,158					None		
Burlington, W. Va.		360	45,000	None	360			
Fort Ashby, W. Va.		720	90,000	35	470			
Pattersons Cr., W. Va.		315	39,000	None	315			
Main Stem North Branch	87-0,158							
Davis Coal Co., W. Va.						500,000	-	Fines, Silt

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
North Branch Potomac								
Main Stem North Branch (Continued)	87-0,158							
Bayard, W. Va.		530	67,000	35	350			
Fairfax Coal Co.						800,000	Screens	Fines, Silt
Kitzmiller, Md.		580	72,000	35	380			
Westernport, Md.		3,500	410,000	None	3,500			
Piedmont, W. Va.		2,400	290,000	None	2,400			
Luke, Md.		900	110,000	None	900			
W. Va. Pulp & Paper Co.						40,000,000	-	300,000
Keyser, W. Va.		4,650	330,000	None	4,650			
Royal Dairy Co.						35,000	None	110
Mason Dairy Co.						35,000	None	110
Celanese Corporation						3,600,000	-	59,000
Cumberland, Md.		45,000	10,100,000	None	45,000			
Pittsburgh Plate Glass		3,000	75,000	35	1,950	2,000,000	Lagoons	
Kelly Springfield Co.						12,000,000	None	Heat
Union Tanning Co.						119,000	45	3,250
Cumberland Laundry Co.						25,000	-	-
N. and G. Taylor Co.						100,000	-	-
Ridgely, W. Va.		1,000	38,000	35	650			
Koppers Co., W. Va.		135	3,000	75	35			
South Branch Potomac								
North Fork	73,158	None				None		
South Fork	57,158							
Moorefield, W. Va.		950	105,000	None	950			
Rockingham Poultry Co.		125	3,000	None	125	135,000	None	3,350
Loewengart Tanning Co.						100,000	45	2,700

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
Main Stem South Branch	85-0,158					None		
Franklin, W. Va.		540	45,000	35	350			
Petersburg, W. Va.		1,000	100,000	None	1,000			
Romney, W. Va.		1,800	108,000	80	360			
School for Deaf		400	40,000	35	260			
Cacapon River	121					None		
Lost River State Park		780	20,000	50	390			
Little Tonoloway Creek	112	Nore				None		
Warm Springs Run	111							
Berkeley Springs, W. Va.		700	170,000	None	700			
Aulabaugh Bros.						18,000	None	900
Penn. Sand-Glass Co.		225	5,000	None	225	180,000	Settling	Silt, Clay
Sleepy Creek	106	None				None		
Licking Creek	104	None				None		
Back Creek	99					None		
Jones Springs, W. Va.		135	16,000	None	135			
Hedgesville, W. Va.		380	47,000	None	380			
Conococheague Creek	84							
Scotland Orphanage, Pa.		850	100,000	75	210			
S. G. Dixon TB Hospital, Pa.		1,700	300,000	75	430			
Chambersburg, Pa.		18,500	1,500,000	35	12,000			
H. J. Heinz Co.						500,000	85	3,600
Path Valley Esso						25,000	80	-

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
Conococheague Creek (Continued)	84							
Mercersburg, Pa.		2,400	185,000	75	600			
Loewengart Tanning Co.						220,000	40	6,600
Greencastle, Pa.		2,800	330,000	-	4,100			
Greencastle Packing Co.						12,000	85	1,250
Kemps Mill, Md.		100	3,000	None	100			
Williamsport, Md.		830	35,000	27.5	600			
W. D. Byron Co.		160	4,000	90	36	55,000	40	8,000
Opequon Creek	75							
Winchester, Va.		14,400	2,530,000	75	3,600			
O'Sullivan Rubber Co.		500	12,000	35	325		Settling	-
Clearbrook Woolen Co.						65,000	Land	-
Middleway, Va.		685	85,000	35	445			
Inwood, W. Va.		360	19,000	None	360			
Musselman Canning Co.						300,000	60	9,000
Leetown, W. Va.		270	33,000	None	270			
Kearneysville, W. Va.		630	78,000	None	630			
Martinsburg, W. Va.		18,000	2,500,000	33	12,000			
National Fruit Co.						380,000	Filters	-
Interwoven Co.						120,000	-	-
Standard Lime & Stone Co.		600	15,000	50	300	140,000	-	Silt, Clay
Blair Limestone Co.						125,000	Settling	Silt, Clay
Antietam Creek	53							
Fayetteville, Pa.		2,700	60,000	100	(Land)0			
Waynesboro, Pa.		9,800	1,100,000	75	2,450			
E. U. B. Orphanage, Pa.		350	21,000	75	85			
Smithsburg, Md.		680	87,000	35	440			

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
South Fork (Continued)	54.5-44							
Verona Sanitary Dist., Va.		1,500	187,000	35	970			
Amer. Safety Razor Co.		1,200	144,000	35	780			
Western State Hospital		1,500	143,000	75	290			
Woodrow-Wilson School		4,500	112,000	35	2,925			
Skyland-Swannanoa, Va.		250	31,000	75	60			
Greenville State Welfare		150	19,000	75	38			
Harrisonburg, Va.		10,000	1,250,000	35	6,500			
Dayton, Va.		1,080	135,000	None	1,080			
Bridgewater, Va.		880	110,000	None	880			
Elkton, Va.		1,600	200,000	None	1,600			
Merck & Co.						6,735,000	76	31,620
Shenandoah, Va.		1,800	710,000	35	1,170			
Stanley, Va.		360	45,000	None	360			
Luray, Va.		3,350	275,000	35	2,180			
Virginia Oak Tannery						280,000	40	6,840
Stauffer Chem. Co.		45	11,000	75	12	25,000		
Front Royal, Va.		8,500	810,000	35	5,500			
American Viscose Corp.						4,620,000		22,990
Old Virginia Packing Co.								
Allied Chem. and Dye								
Beef Cattle Research		50	12,000	75	12			
Viscose City, Va.		400	50,000	75	100			
Main Stem Shenandoah	54.5-0,44							
Berryville, Va.		1,500	187,000	35	970			
Charlestown, W. Va.		1,500	155,000	40	900			
Halltown, W. Va.		None						
Valley Board Co.		160	4,000	None	160	2,225,000	None	-
Michigan Limestone, W. Va.						530,000	Settling	Silt, Clay

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
Antietam Creek (Continued)	53							
North American Cement Co., Md.						18,600,000	None	Silt, Clay
Hagerstown, Md.		33,000	5,235,000	83	5,700			
Western Maryland RR		2,000	50,000	83	140	325,000	Preventive	-
Mullendore Slaughter						18,000	50	1,000
Fairchild Aircraft Co.		7,500	165,000	75	1,870	465,000	None	Plating
Funkstown, Md.		800	100,000	75	200			
Maryland State Penitentiary		75	9,000	35	50			
Maryland State Reformatory		400	50,000	35	260			
Boonsboro, Md.		None						
Keedysville, Md.		317	47,000	None	375			
Shenandoah River	44							
North Fork	54.5-44							
Broadway, Va.		540	130,000	35	350			
Shen-Valley Packers						200,000	95	700
Timberville, Va.		120	15,000	None	120			
Rockingham Poultry Co-op.						545,000	82	9,810
Valley Housing Corp., Va.		300	37,000	35	195			
New Market, Va.		950	120,000	None	950			
Mount Jackson, Va.		650	80,000	None	650			
Edinburg, Va.		480	60,000	None	480			
Woodstock, Va.		1,750	182,000	None	1,750			
Strasburg, Va.		1,600	200,000	None	1,600			
South Fork	54.5-44							
Waynesboro, Va.		20,000	2,500,000	75	5,000			
E. I. du Pont de Nemours						12,880,000	56	21,180
Crompton-Shenandoah Co.						2,213,000	46.5	16,050
Staunton, Va.		15,000	1,200,000	35	7,500			

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
Main Stem Shenandoah (Continued)	54.5-0,44							
Blair Limestone, W. Va.						720,000	Settling	Silt, Clay
Catoctin Creek, Md.	35					None		
Meyersville, Md.		None						
Middletown, Md.		840	105,000	35	550			
Burkettsville, Md.		None						
Catoctin Creek, Va.	33							
Purcellville, Va.		850	105,000	35	650			
J. Lynn Cornwell Packing						110,000	80	265
Waterford, Va.		None						
Lovettsville, Va.		300	37,000	None	300			
Tuscarora Creek	28	None				None		
Monocacy River	26							
Mont Alto, Pa.		990	63,000	100	(Land)0			
Gettysburg, Pa.		7,500	500,000	95	480			
Littlestown, Pa.		2,850	140,000	75	710			
Fairfield, Pa.		385	10,000	100	(Land)0			
Funkhouser Co., Pa.						108,000	Lagoons	In-organic
Knouse Food Corp., Pa.						100,000	Land	-
B. H. Shriver Co., Pa.						83,000	Land	-
Emmitsburg, Md.		1,050	160,000	33.5	700			
St. Mary's College		600	75,000	33.5	400			
St. Joseph's Academy		400	100,000	35	260			
A. W. Feeser Co., Md.						35,000	40	1,050

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
Monocacy River (Continued)	26							
Taneytown, Md.		1,800	200,000	75	450			
Cambridge Rubber Co.						48,000	-	Oil
Essig Packing Co.						12,000	Septic	-
E. J. Nusbaum Co.						50,000	Screens	2,500
A. W. Feeser Co.						35,000	40	1,050
Westminster, Md.		4,692	580,000	77	630			
Mount Pleasant Canning						30,000	10	1,350
Willow Farm Dairy Co.						40,000	Preventive	128
New Windsor, Md.		640	80,000	None	640			
Western Maryland Dairy						30,000	Preventive	23
Farmers' Cooperative						15,000	-	Heat
Joseph H. Weller Co., Md.						15,000	None	750
Union Bridge, Md.		750	94,000	35	490			
Yingling Bros.						10,000	Preventive	1,120
A. W. Feeser Co., Md.						60,000	40	3,000
George W. Magin Co., Md.						20,000	-	Heat
Western Maryland Dairy						125,000	Preventive	625
Thurmont, Md.		2,500	500,000	75	630			
Thurmont Rendering Co.						-	Septic	-
Howard Lotte & Co.						18,000	(City)75	500
Fraley's Meats, Md.						9,000	-	1,000
Maryland TB Sanitarium		600	88,000	75	150			
Woodsboro, Md.		380	48,000	None	380			
Castle Cheese Co., Md.						1,000	Septic	369
Walkersville, Md.		680	85,000	None	680			
Western Maryland Dairy						36,000	Preventive	180
Camp Detrick, Md.		500	62,000	75	125			
Frederick, Md.		19,000	2,800,000	-	24,000			
Everedy Co.						150,000	Recovery	Plating

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
Monocacy River (Continued)	26							
Mount Airy, Md.		-						
Western Maryland Dairy						11,000	Preventive	35
George McComas & Co., Md.						24,000	Land	-
Goose Creek	15							
Middleburg, Va.		500	75,000	75	125			
Leesburg, Va.		2,000	250,000	75	500			
Goose Creek Country Club		300	8,000	75	78			
Foxcraft School, Va.		195	5,000	75	50			
Seneca Creek	8	None				None		
Sugarland Creek	7							
Herndon, Va.		1,100	132,000	75	275			
Muddy Branch	5							
Gaithersburg, Md.		4,000	500,000	75	1,000			
Potomac River	158-0							
Paw Paw, W. Va.		800	43,000	35	520			
Hancock, Md.		780	310,000	None	780			
Williamsport, Md.		970	65,000	35	845			
Du Pont, Falling Waters		419	10,000	50	210	500,000	-	Explosives
Sharpsburg, Md.		780	100,000	35	500			
Shephardstown, W. Va.		2,000	90,000	None	2,000			
Meere Sand & Gravel Co.						288,000	Settling	Silt, Clay
Baltimore & Ohio RR						1,000	Screens	Oil
Harpers Ferry and Bolivar, W. Va.		250	30,000	None	250			

Waste Disposal Data

Location of Municipality or Industry	Mileage to Great Falls	Pop. Served	Domestic GPD	Domestic % Treat.	Domestic P.E. Disch.	Industrial GPD	Industrial % Treat.	Industrial P.E. Disch.
Potomac River (Continued)	158-0							
Brunswick, Knoxville, and Weverton, Md.		3,600	400,000	50	1,800			
Great Falls Park, Va.		3,000	375,000	None	3,000			

PART III

APPENDIX III

STREAM SURVEY DATA

STREAM SURVEY DATA

Tributary	Station No.	Mileage to Potomac	Mileage to Great Falls	1958 Date	Temp. °C.	D.O. ppm	% Saturation	BOD ppm	Coliforms per 100 ml.	pH	Total Alkalinity ppm	Hardness ppm	Turbidity ppm	Total Solids ppm	Suspended Solids ppm	Iron ppm	Manganese ppm	Tannin ppm
Patterson's Creek	A-1	3.3	178	9/11	18	6.54	89	0.90	130	7.6	56	116	<25	202	-	-	-	-
of North Branch				9/18	20	7.50	82	0.70	400	7.7	86	116	<25	171	-	-	-	-
Potomac River				9/25	20	6.00	67	0.65	150	7.8	86	116	<25	190	-	-	-	-
				10/2	13	9.00	85	0.45	170	7.8	89	119	<25	-	-	-	-	-
				10/9	13	9.30	88	0.60	<25,000	7.9	89	119	<25	-	-	-	-	-
				10/16	13	8.30	78	0.80	10,000	7.8	91	122	<25	-	-	-		-
North Fork of	A-2	[illegible]	248	9/10	16	9.00	91	0.50	370	7.7	65	65	<25	89	-	-	-	-
South Branch				9/17	19	7.30	78	0.70	600	7.2	70	77	<25	126	-	-	-	-
Potomac River				9/24	17	9.60	95	0.65	850	6.0	65	57	<25	90	-	-	-	-
				10/1	14	9.05	87	0.85	280	7.7	69	70	<25	-	-	-	-	-
				10/8	11	10.05	90	0.30	350	7.9	70	72	<25	-	-	-	-	-
				10/15	12	9.30	86	0.55	900	7.9	75	75	<25	-	-	-	-	-
South Fork of	A-3	[illegible]	[illegible]	9/10	17	7.60	78	0.70	170	7.7	79	87	<25	126	-	-		-
South Branch				9/24	17	7.70	79	0.30	500	7.8	83	93	<25	120	-	-	-	-
Potomac River				10/1	16	7.85	78	0.40	530	7.9	83	91	<25	-	-	-	-	-
				10/8	12	9.10	84	0.40	300	7.7	84	98	<25	-	-	-	-	-
				10/15	14	7.75	75	0.50	240	7.7	87	104	<25	-	-	-	-	-
	A-4	[illegible]	[illegible]	9/10	20	7.50	83	2.60	33,000	7.9	82	95	<25	139	3	-	-	2.10
				9/17	23	6.20	72	2.20	40,000	7.8	86	100	<25	203	6	-	-	2.45
				9/24	20	5.70	62	2.45	55,000	7.8	90	104	<25	175	5	-	-	7.00
				10/1	16	3.40	34	16.00	550,000	7.9	112	112	30	-	-	-	-	22.40
				10/8	14	7.10	69	3.35	130,000	7.7	91	108	<25	-	-	-	-	4.55
				10/15	16	7.25	73	2.50	17,000	7.7	93	109	<25	-	-	-	-	2.70
South Branch of	A-5	[illegible]	277.5	9/10	16	8.60	85	0.85	-	7.9	102	106	<25	130	-	-	-	-
Potomac River				9/17	20	7.20	79	0.80	7,300	7.9	104	108	<25	156	-	-	-	-
				9/24	17	8.70	89	0.85	5,500	8.1	104	108	<25	142	-	-	-	-
				10/1	14	8.45	81	0.70	7,900	8.0	106	108	<25	-	-	-	-	-
				10/8	10	9.50	84	0.50	5,200	7.9	107	110	<25	-	-	-	-	-
				10/15	12	8.75	81	0.40	6,200	8.1	110	110	<25	-	-	-	-	-
	A-6	47.9	275.5	9/10	20	8.60	94	0.35	680	7.9	96	109	<25	157	-	-	-	-
				9/17	22	7.60	88	1.00	370	8.1	95	112	<25	174	-	-	-	-
				9/24	15	8.10	82	0.55	1,400	8.0	92	104	<25	153	-	-	-	-
				10/1	16	8.60	87	0.45	300	8.1	100	116	<25	-	-	-	-	-
				10/8	12	9.55	88	0.35	230	8.0	103	117	<25	-	-	-	-	-
				10/15	15	9.50	94	0.30	220	8.0	106	124	<25	-	-	-	-	-
	A-7	6	281	9/10	20	8.10	89	1.00	500	8.1	94	110	<25	154	-	-	-	0.40
				9/17	22	6.35	72	1.00	5,800	7.8	102	124	<25	199	-	-	-	0.55
				9/24	19	7.90	85	0.40	3,700	7.5	96	108	<25	145	-	-	-	0.25
				10/1	16	7.70	77	0.45	7,700	7.9	105	122	<25	-	-	-	-	0.20
				10/8	13	8.95	85	0.40	8,700	7.9	106	127	<25	-	-	-	-	0.30
				10/15	15	8.05	79	0.40	7,300	7.8	109	131	<25	-	-	-	-	0.45

STREAM SURVEY DATA

Tributary	Station No.	Mileage to Potomac	Mileage to Great Falls	1958 Date	Temp. °C.	D.O. ppm	% Saturation	BOD ppm	Coliforms per 100 ml.	pH	Total Alkalinity ppm	Hardness ppm	Turbidity ppm	Total Solids ppm	Suspended Solids ppm	Iron ppm	Manganese ppm	Tannin ppm
South Branch of	A-8	94.5	212.5	9/10	20	8.20	89	0.70	9,000	7.9	90	111	<25	155	6	-	-	0.50
Potomac River				9/17	24	7.50	88	1.05	6,800	8.0	95	112	<25	197	8	-	-	0.50
(Continued)				9/24	20	8.50	93	0.65	2,300	7.9	93	108	<25	104	9	-	-	0.60
				10/1	16	7.65	77	1.75	51,000	7.9	99	119	<25	-	-	-	-	2.25
				10/8	13	9.40	88	1.70	7,000	8.0	100	120	<25	-	-	-	-	0.95
				10/15	16	8.65	87	0.85	3,800	7.9	100	121	<25	-	-	-	-	0.50
	A-9	35	193	9/10	21	8.20	91	1.20	300	8.1	93	112	<25	151	-	-	-	-
				9/17	24	8.10	95	0.70	250	8.1	94	115	<25	194	-	-	-	-
				9/24	22	8.35	95	1.05	650	8.0	96	119	<25	185	-	-	-	-
				10/1	17	9.00	92	0.50	310	8.0	95	113	<25	-	-	-	-	-
				10/8	15	10.25	101	0.75	94	8.2	98	123	<25	-	-	-	-	-
				10/15	17	9.55	98	1.10	200	8.2	96	123	<25	-	-	-	-	-
	B-2	16	174	9/11	14	8.15	85	0.95	200	7.8	90	117	<25	181	7	0.50	0.20	0.60
				9/18	23	6.95	80	0.65	450	7.9	92	112	<25	158	8	0.16	0.03	0.35
				9/25	21	7.50	83	0.80	170	8.0	95	117	<25	185	9	0.22	0.07	0.45
				10/2	14	9.00	87	0.45	580	8.0	93	113	<25	-	-	0.20	0.03	0.20
				10/9	14	9.20	89	0.50	170	8.1	98	122	<25	-	-	0.40	0.08	0.45
				10/16	15	8.80	87	0.90	80	8.1	98	125	<25	-	-	0.16	2.50	0.85
East Fork of	B-3	0.5, 37	158.5	9/11	17	8.05	82	0.95	280	7.6	65	72	<25	138	-	-	-	-
Cacapon River				9/17	21	7.05	78	0.70	630	7.9	90	96	<25	141	-	-	-	-
				9/25	18	7.60	80	0.50	450	7.6	67	72	<25	115	-	-	-	-
				10/2	13	8.70	82	0.30	450	7.7	68	74	<25	-	-	-	-	-
				10/9	13	9.10	86	0.55	350	7.9	78	83	<25	-	-	-	-	-
				10/16	13	8.10	76	1.25	280	7.7	86	92	<25	-	-	-	-	-
Cacapon River	B-4	37.5	158.5	9/11	17	8.05	82	0.75	75	7.9	87	93	<25	147	-	-	-	-
				9/18	20	7.20	79	0.55	700	7.8	76	82	<25	124	-	-	-	-
				9/25	19	7.90	80	0.55	100	8.0	89	95	<25	127	-	-	-	-
				10/2	14	8.75	85	0.25	250	7.9	91	97	<25	-	-	-	-	-
				10/9	13	9.50	89	0.70	58	8.2	93	100	<25	-	-	-	-	-
				10/16	14	8.80	85	0.65	75	8.5	101	102	<25	-	-	-	-	-
	B-6	8.5	121.5	9/11	19	9.00	96	0.70	180	8.0	75	80	<25	129	3	-	-	-
				9/18	22	8.30	94	0.75	180	8.0	78	85	<25	124	3	-	-	-
				9/25	20	8.60	94	0.65	220	8.1	81	87	<25	112	3	-	-	-
				10/2	14	9.50	92	0.45	1,500	8.0	82	88	<25	-	-	-	-	-
				10/9	14	9.75	94	0.45	25,000	8.1	82	88	<25	-	-	-	-	-
				10/16	14	9.00	87	0.40	14,000	7.9	88	95	<25	-	-	-	-	-
Little Tonoloway	C-1	1	113	9/12	14	5.15	50	13.00	5,000	7.6	94	114	<25	140	-	-	-	-
Creek				9/15	17	4.00	41	12.50	18,000	7.9	95	116	<25	177	-	-	-	-
				9/22	24	6.00	76	>32,000	8,300	7.3	104	124	<25	196	-	-	-	-
				9/30	14	9.00	87	1.10	400	7.9	83	100	<25	-	-	-	-	-
				10/7	10	9.70	86	1.50	120	7.7	97	124	<25	-	-	-	-	-
				10/14	12	8.70	80	1.80	150	7.5	102	133	<25	-	-	-	-	-

STREAM SURVEY DATA

Tributary	Station No.	Mileage to Potomac	Mileage to Great Falls	1958 Date	Temp. °C.	D.O. ppm	% Saturation	B.O.D. ppm	Coliforms per 100 ml.	pH	Total Alkalinity ppm	Hardness ppm	Turbidity ppm	Total Solids ppm	Suspended Solids ppm	Iron ppm	Manganese ppm	Tannin ppm
Warm Spring Run	[illegible]	1	112	9/9	15	8.40	83	5.45	-	7.6	107	-	6,800	9,810	9,232	-	-	-
				9/11	12	8.45	78	6.95	-	7.7	101	-	7,200	10,092	9,472	-	-	-
				9/12	13	8.90	84	13.80	-	7.8	-	-	8,000	11,348	10,712	-	-	-
				9/15	14	9.05	87	8.15	-	8.2	-	-	800	2,240	1,963	-	-	-
				9/18	20	7.85	86	<26.80	-	7.7	-	-	50,000	52,492	10,064	-	-	-
				9/22	16	8.75	97	2.05	-	8.0	-	-	180	253	100	-	-	-
				9/25	17	8.00	82	10.20	-	7.8	-	-	12,500	9,864	9,436	-	-	-
				9/30	12	9.40	87	5.70	-	7.9	-	-	7,600	7,226	6,824	-	-	-
				10/2	10	10.10	89	5.84	-	7.9	-	-	8,500	8,194	7,820	-	-	-
				10/7	6	10.70	86	7.95	-	7.8	-	-	10,800	10,698	10,084	-	-	-
				10/13	12	9.25	84	5.85	-	7.9	-	-	6,800	11,048	10,400	-	-	-
				10/14	11	9.60	87	7.85	-	7.9	-	-	9,600	11,272	10,808	-	-	-
				10/16	11	9.40	85	7.15	-	7.9	-	-	6,300	8,564	8,044	-	-	-
Sleepy Creek	[illegible]	7.5	113.5	9/12	15	7.70	76	0.80	150	7.5	41	45	<25	64	-	-	-	-
				9/15	16	7.90	80	0.15	200	7.6	41	42	<25	93	-	-	-	-
				9/22	17	7.30	75	1.45	510	7.5	39	40	<25	50	-	-	-	-
				9/30	14	8.55	82	0.65	150	7.6	46	47	<25	-	-	-	-	-
				10/7	10	9.20	81	0.70	80	7.4	46	47	<25	-	-	-	-	-
				10/14	12	8.05	74	1.25	140	7.5	59	60	<25	-	-	-	-	-
Back Creek	[illegible]	27.5	139.5	9/9	20	8.80	96	0.80	170	7.8	112	122	<25	162	-	-	-	-
				9/16	20	8.50	93	1.15	140	8.0	120	129	<25	164	-	-	-	-
				9/23	17	8.50	87	0.64	140	7.9	123	132	<25	166	-	-	-	-
				9/29	15	8.10	80	0.80	270	8.0	118	126	<25	-	-	-	-	-
				10/6	11	9.25	84	0.40	180	8.0	126	133	<25	-	-	-	-	-
				10/13	12	9.25	85	1.00	550	7.9	131	140	<25	-	-	-	-	-
	[illegible]	7.5	106.5	9/12	15	8.15	80	0.40	230	7.9	107	114	<25	134	-	-	-	-
				9/15	17	8.05	83	0.25	150	8.1	108	112	<25	162	-	-	-	-
				9/22	18	7.90	79	0.65	1,600	8.0	108	116	<25	142	-	-	-	-
				9/30	14	7.80	75	0.35	420	7.9	114	123	<25	-	-	-	-	-
				10/7	9	9.05	78	1.40	190	7.9	120	128	<25	-	-	-	-	-
				10/14	12	7.40	68	1.35	420	7.8	122	131	<25	-	-	-	-	-
Conococheague Creek	[illegible]	46.5	136.5	9/10	16	3.65	39	3.25	10,000	7.7	166	187	<25	249	7	-	-	-
				9/17	21	2.10	23	2.15	52,000	7.9	177	190	<25	245	5	-	-	-
				9/24	17	3.40	35	3.60	43,000	8.0	148	166	<25	231	7	-	-	-
				10/1	16	3.60	36	3.70	25,000	7.6	144	161	<25	-	-	-	-	-
				10/8	13	3.60	34	3.45	18,000	7.7	156	174	<25	-	-	-	-	-
				10/15	14	3.20	31	3.30	49,000	7.7	166	182	<25	-	-	-	-	-
	[illegible]	71	105	9/10	18	7.30	77	1.55	7,700	8.1	164	182	<25	231	8	-	-	0.85
				9/17	21	5.05	56	0.85	400	8.0	169	190	<25	258	7	-	-	0.95
				9/24	17	7.80	82	1.75	4,600	8.2	127	146	<25	203	6	-	-	0.75
				10/1	15	7.70	76	1.50	470	8.1	140	160	<25	-	-	-	-	[illegible]
				10/8	11	10.25	91	0.80	430	8.3	160	180	<25	-	-	-	-	[illegible]
				10/15	12	6.40	77	1.00	78	8.0	170	155	<25	-	-	-	-	1.60

Tributary	Station No.	Mileage to Potomac	Mileage to Great Falls	1956 Date	Temp. °C.	D.O. ppm	% Saturation	BOD ppm	Coliforms per 100 ml.	pH	Total Alkalinity ppm	Hardness ppm	Turbidity ppm	Total Solids ppm	Suspended Solids ppm	Iron ppm	Manganese ppm	Tannin ppm
Conococheague	4-3	1	85	9/10	20	8.15	89	1.50	530	8.3	154	176	<25	231	14	-	-	-
Creek				9/17	20	7.10	80	0.55	880	8.1	123	144	<25	207	11	-	-	-
(Continued)				9/24	18	8.70	91	1.50	730	8.4	114	132	<25	209	21	-	-	-
				10/1	16	9.55	96	1.25	700	8.5	137	155	<25	-	-	-	-	-
				10/8	13	11.30	107	0.85	260	8.6	138	156	<25	-	-	-	-	-
				10/15	13	9.35	88	1.00	260	8.2	147	165	<25	-	-	-	-	-
Opequon Creek	3-2	22.5	97.9	9/9	16	9.10	92	1.40	26,000	8.1	252	279	<25	346	-	-	-	-
				9/16	18	7.60	80	1.20	41,000	8.1	258	271	<25	357	-	-	-	-
				9/23	16	7.20	73	1.55	27,000	7.9	236	256	<25	317	-	-	-	-
				9/29	14	8.25	80	1.00	1,100	8.1	258	283	<25	-	-	-	-	-
				10/6	11	8.85	80	0.60	12,000	8.0	257	287	<25	-	-	-	-	-
				10/13	11	8.25	75	1.20	42,000	7.9	260	284	<25	-	-	-	-	-
	3-6	8.3	83.5	9/12	14	6.30	61	11.60	180,000	8.0	241	274	<25	332	-	-	-	-
				9/19	16	7.00	71	0.90	990,000	8.2	509	244	700	1,102	774	-	-	-
				9/22	17	6.85	70	1.65	150,000	8.1	530	262	380	788	450	-	-	-
				9/30	14	5.60	54	4.30	200,000	8.2	263	279	<25	376	24	-	-	-
				10/7	9	7.20	63	5.75	47,000	8.1	258	280	<25	-	-	-	-	-
				10/14	12	5.85	54	7.45	100,000	7.9	270	287	<25	-	-	-	-	-
Antietam Creek	4-5	25	81	9/10	16	7.60	75	1.65	7,400	8.0	159	184	<25	265	28	-	-	-
				9/17	26	6.10	67	1.60	6,200	8.0	163	192	<25	267	20	-	-	-
				9/24	16	7.49	79	1.75	4,850	7.9	158	180	<25	250	22	-	-	-
				10/1	15	8.30	82	1.00	23,000	8.0	155	180	30	-	-	-	-	-
				10/8	11	8.90	80	1.10	8,000	8.1	156	130	<25	-	-	-	-	-
				10/15	11	8.50	77	1.25	7,300	8.0	168	191	<25	-	-	-	-	-
	4-6	18	74	9/10	15	6.30	64	5.40	>70,000	7.8	185	216	<25	303	16	-	-	-
				9/17	23	5.50	65	4.85	1,300,000	8.0	156	221	<25	328	13			
				9/24	20	6.40	70	4.45	<3,000	7.7	154	176	<25	266	23	-	-	-
				10/1	18	7.25	76	7.80	160,000	7.9	178	207	<25	-	-	-	-	-
				10/8	15	7.40	73	2.85	300,000	7.9	192	222	<25	-	-	-	-	-
				10/15	17	6.60	68	2.75	1,250,000	7.9	198	226	<25	-	-	-	-	-
	4-7	22	64	9/10	15	6.75	77	1.70	4,700	8.0	149	224	<25	311	-	-	-	-
				9/17	21	6.65	74	1.15	2,490	8.0	154	267	<25	331	-	-	-	-
				9/24	18	7.70	81	1.60	13,000	7.9	162	190	<25	294	-	-	-	-
				10/1	16	8.05	88	1.70	7,700	8.0	156	184	<25	-	-	-	-	-
				10/8	13	8.70	82	1.20	13,300	8.1	183	200	<25	-	-	-	-	-
				10/15	14	8.00	77	0.95	2,300	8.0	192	208	<25	-	-	-	-	-
	4-8	5.9	95.5	9/12	15	8.65	85	1.30	1,800	8.2	156	222	<25	308	-	-	-	-
				9/19	17	8.70	89	0.95	770	7.8	195	208	<25	304	-	-	-	-
				9/26	18	8.15	85	1.35	7,200	8.0	154	179	30	292	-	-	-	-
				10/3	15	8.55	86	1.85	5,100	8.1	123	150	50	-	-	-	-	-
				10/7	11	[illegible]	[illegible]	0.65	[illegible]	[illegible]	[illegible]	[illegible]	<25	-	-	-	-	-
				10/14	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	196	[illegible]	<25	-	-	-	-	-

STREAM SURVEY DATA

Tributary	Station No.	Mileage to Potomac	Mileage to Great Falls	1958 Date	Temp. °C.	D.O. ppm	% Saturation	B.O.D. ppm	Coliforms per 100 ml.	pH	Total Alkalinity ppm	Hardness ppm	Turbidity ppm	Total Solids ppm	Suspended Solids ppm	Iron ppm	Manganese ppm	Tannin ppm
Shenandoah River	S-3	19.5	49.9	9/2	23	8.30	93	1.80	170	8.3	102	148	30	272	-	-	-	-
				9/16	22	8.80	100	1.75	67	8.4	130	177	<25	325	-	-	-	-
				9/23	20	8.80	90	1.50	170	8.2	141	191	<25	305	-	-	-	-
				9/29	18	8.65	91	2.35	7,500	8.4	147	188	<25	-	-	-	-	-
				10/6	15	9.15	90	1.70	450	8.8	155	197	<25	-	-	-	-	-
				10/13	16	9.80	95	2.10	2,500	8.4	151	180	<25	-	-	-	-	-
	S-4	1	45	9/9	22	8.90	101	2.35	700	8.5	116	147	30	273	25	0.20	0.10	0.90
				9/11	19	8.90	95	2.70	1,700	8.3	114	152	<25	272	23	0.94	0.20	0.80
				9/16	20	7.65	84	1.70	1,400	8.3	140	176	25	311	26	0.52	0.16	0.75
				9/23	19	8.60	92	1.90	500	8.2	143	188	30	289	24	0.52	0.09	0.90
				9/29	19	8.55	88	5.30	>29,000	8.2	143	180	45	-	-	0.72	0.09	0.70
				10/6	13	9.65	91	6.80	8,700	8.2	156	205	35	-	-	0.70	0.60	1.15
				10/13	14	9.90	97	2.65	32,000	8.1	153	200	<25	-	-	0.30	0.08	0.30
Antietam Creek	S-4	3	50	9/9	17	7.05	73	1.40	1,700	7.4	54	63	70	186	-	-	-	-
				9/16	19	6.80	73	1.40	1,200	8.0	50	54	50	155	-	-	-	-
				9/23	16	8.00	80	1.80	14,000	7.5	41	48	35	106	-	-	-	-
				9/29	15	7.65	78	1.60	11,200	7.7	55	62	35	-	-	-	-	-
				10/6	12	8.45	79	1.35	5,500	7.6	47	52	<25	-	-	-	-	-
				10/13	12	9.30	86	1.55	42,000	7.6	50	54	<25	-	-	-	-	-
Dry Creek of Monocacy River	P-3	3.98.5	89.4	9/8	21	6.00	67	4.65	530	7.5	143	128	<25	323	-	-	-	-
				9/15	16	3.90	15	4.35	90	7.7	160	126	<25	332	-	-	-	-
				9/22	17	6.75	69	2.60	>16,000	7.5	64	100	50	219	-	-	-	-
				9/30	16	5.20	50	3.95	61,000	7.5	75	108	<25	-	-	-	-	-
				10/7	5	4.30	37	5.90	4,600	7.4	117	138	<25	-	-	-	-	-
				10/14	12	3.80	30	6.40	5,200	7.7	164	147	<25	-	-	-	-	-
Monocacy River	P-4	61	67	9/8	22	7.85	89	2.80	13,000	7.5	83	96	<25	147	-	-	-	-
				9/15	18	7.90	84	4.55	5,400	8.2	83	94	<25	157	-	-	0.08	-
				9/22	18	6.90	72	2.75	26,000	7.6	69	82	95	210	-	-	-	-
				9/30	14	7.44	75	2.50	2,500	7.4	40	56	90	-	-	-	-	-
				10/7	10	9.65	85	0.70	720	7.7	60	78	<25	-	-	-	-	-
				10/14	13	9.80	92	1.25	770	7.9	76	91	<25	-	-	-	-	-
	P-5	33	44	9/8	23	4.20	47	1.65	17,000	7.4	92	102	<25	154	-	-	-	-
				9/15	18	4.40	57	1.95	7,400	7.9	95	108	<25	176	-	-	0.18	-
				9/22	18	5.70	6	2.45	53,000	7.6	66	76	75	195	-	-	-	-
				9/30	16	4.55	56	2.10	73,000	7.6	69	81	75	-	-	-	-	-
				10/7	11	5.50	50	2.45	58,000	7.6	85	100	30	-	-	-	-	-
				10/14	13	6.30	60	1.90	35,100	7.5	89	101	30	-	-	-	-	-
	P-6	2	38	9/8	22	6.85	74	1.80	1,000	7.6	94	107	<25	168	12	-	-	-
				9/15	19	7.40	81	1.25	290	8.0	98	114	<25	164	30	-	-	-
				9/22	20	6.60	71	7.80	16,000	8.4	87	91	70	202	61	-	-	-
				9/30	17	7.40	76	1.10	4,000	7.7	75	89	50	-	-	-	-	-
				10/7	18	8.60	85	1.30	1,800	7.8	83	33	80	-	-	-	-	-
				10/14	16	8.50	82	1.60	1,600	7.7	91	107	70	-	-	-	-	-

STREAM SURVEY DATA

Potomac River	Station No.	Mileage to Mouth	Mileage to Great Falls	1958 Date	Temp. °C.	D.O. ppm	% Saturation	B.O.D. ppm	Coliform per 100 ml.	pH	Total Alkalinity ppm	Hardness ppm	Turbidity ppm	Total Solids ppm	Suspended Solids ppm	Iron ppm	Manganese ppm	Tannin ppm
Paw Paw, West	P-5	276.3	149.3	9/3	28	6.65	73	1.35	770	7.5	64	135	<25	256	18	0.70	0.30	1.35
Virginia				9/11	18	4.10	74	2.10	7,700	7.7	70	142	<25	273	13	0.52	0.40	1.95
				9/18	22	6.60	75	1.25	470	7.7	67	125	<25	216	7	0.44	0.09	0.70
				9/25	21	6.60	73	1.90	1,500	7.7	69	136	<25	236	11	0.73	0.60	1.30
				10/2	14	8.60	83	1.65	530	7.7	71	150	<25	-	-	0.58	0.13	0.80
				10/9	15	8.90	88	4.25	70,000	7.9	73	152	<25	-	-	0.78	0.09	1.70
				10/16	15	7.90	77	2.00	3,200	7.8	80	165	<25	-	-	1.00	0.27	2.30
Hancock,	P-4	239	112	9/3	28	8.40	91	0.30	53	7.7	67	119	35	249	62	0.34	0.20	0.93
Maryland				9/12	16	8.70	91	0.40	54	8.0	68	122	<25	209	13	0.28	0.10	0.60
				9/15	19	8.05	86	0.45	110	7.3	64	127	<25	227	5	0.12	0.04	0.80
				9/22	15	7.85	84	0.20	380	7.8	69	112	<25	182	4	0.12	0.04	0.45
				9/30	17	9.00	92	0.80	50	8.0	76	120	<25	-	-	0.08	0.03	0.30
				10/7	12	10.00	92	1.20	40	8.0	79	130	<25	-	-	0.20	0.13	0.55
				10/14	13	9.90	94	1.10	55	7.8	79	138	<25	-	-	0.30	0.12	0.80
Williamsport,	P-3	210.9	83.9	9/9	24	10.45	123	1.25	100	7.7	67	116	<25	208	14	0.52	0.10	0.50
Maryland				9/16	22	7.25	82	0.50	120	8.0	73	113	<25	182	6	0.14	0.10	0.30
				9/17	24	8.50	104	0.60	230	8.1	76	128	<25	221	12	0.24	0.06	0.60
				9/24	20	8.60	94	1.10	650	7.4	78	124	<25	206	6	0.14	0.05	0.55
				10/1	18	7.05	74	1.30	180	7.8	82	133	<25	-	-	0.32	0.16	0.40
				10/8	15	10.20	100	1.30	160	7.9	82	128	<25	-	-	0.26	0.17	0.45
				10/15	15	9.45	93	1.00	80	8.0	85	139	<25	-	-	0.20	0.09	0.55
Shepherdstown	[illegible]	183.9	56	9/3	23	8.15	94	0.10	180	8.1	92	128	<25	200	10	0.24	0.10	0.45
West Virginia				9/12	19	10.75	115	1.05	140	8.3	114	147	<25	190	4	0.08	0.10	0.65
				9/19	22	10.90	124	1.65	83	8.2	106	140	<25	206	9	0.12	0.05	0.84
				9/29	20	8.20	90	0.90	230	8.1	113	151	<25	204	6	0.08	0.07	0.70
				9/30	19	10.65	114	1.20	250	8.5	103	143	<25	-	-	0.10	0.04	0.45
				10/7	17	11.00	104	1.40	140	8.1	121	160	<25	-	-	0.16	0.13	0.65
				10/14	14	13.25	124	4.25	130	8.2	101	137	<25	-	-	0.14	0.06	0.60
Brunswick,	[illegible]	168	[illegible]	9/9	20	7.05	77	1.50	200	8.0	106	134	<25	243	16	0.14	0.10	0.75
Maryland				9/11	18	8.60	92	2.25	390	8.3	108	152	<25	240	16	0.28	0.10	0.75
				[illegible]/16	21	6.70	75	1.20	190	8.3	128	160	<25	266	17	0.40	0.18	0.75
				[illegible]	15	7.44	81	1.30	150	8.0	116	152	<25	202	10	0.24	0.06	0.75
				9/29	[illegible]	7.65	80	1.40	7,500	8.0	120	160	<25	-	-	0.42	0.72	0.65
				10/6	[illegible]	8.45	85	1.95	8,600	8.1	139	176	<25	-	-	0.30	0.10	0.80
				10/13	14	5.35	52	1.30	28,000	8.2	124	164	<25	-	-	0.16	0.06	0.65
Point of Rocks,	[illegible]	159.5	32.5	9/3	21	7.45	81	1.50	40	8.3	108	139	<25	223	11	0.32	0.10	0.60
Maryland				9/11	18	8.05	84	1.35	120	8.2	105	139	<25	216	9	0.34	0.10	0.70
				9/16	23	7.45	86	1.15	170	8.4	122	149	<25	272	19	0.60	0.12	0.75
				9/23	18	7.45	82	0.90	500	8.2	119	160	<25	235	11	0.20	0.02	0.75
				9/29	17	8.00	81	4.65	300	8.2	124	164	<25	-	-	0.38	0.06	0.65
				10/6	14	9.00	87	4.30	550	8.2	135	173	<25	-	-	0.24	0.07	0.80
				10/13	14	5.90	56	2.00	4,100	8.3	134	177	<25	-	-	0.26	0.09	0.70

STREAM QUALITY DATA

III - 7

Potomac River	Station No.	Miles to Mouth	Miles to Great Falls	1958 Date	Temp. °C.	D.O. ppm	% Saturation	B.O.D. ppm	Coliform per 100 ml.	pH	Total Alkalinity ppm	Hardness ppm	Turbidity ppm	Total Solids ppm	Suspended Solids ppm	Iron ppm	Manganese ppm	Tannin ppm
Whites Ferry Maryland	P-4	150.5	22.5	9/3	23	7.55	86	1.40	180	8.2	115	145	< 25	272	20	1.66	0.20	0.75
				9/11	16	8.30	87	1.35	580	8.0	95	116	<25	168	19	0.28	0.40	0.72
				9/16	23	7.75	89	2.55	150	8.4	123	160	30	292	27	0.84	3.80	1.10
				9/23	18	6.35	67	1.95	3,000	8.0	61	90	75	187	70	1.56	1.20	0.95
				9/29	17	8.25	86	1.45	550	8.1	94	117	60	-	-	1.08	0.16	0.50
				10/6	14	9.05	87	1.00	2,900	7.9	67	108	60	-	-	1.04	0.13	0.60
				10/13	14	9.70	93	2.05	150	7.8	98	117	45	-	-	1.04	0.14	0.50
Great Falls	P-1	127	0	9/8	24	6.60	78	1.60	230	8.4	73	98	10	146	-	-	-	-
				9/15	21	6.40	93	2.00	280	8.6	94	106	14	166	-	-	-	-
				9/22	19	6.80	72	0.80	600	7.9	80	96	18	167	-	-	-	-
				9/29	20	7.00	76	1.20	130	8.9	83	108	28	175	-	-	-	-
				10/6	16	8.40	80	4.00	86	9.1	81	108	20	163	-	-	-	-
				10/13	14	9.40	92	5.20	-	9.0	89	116	16	185	-	-	-	-

PART III

APPENDIX IV

SURVEY STREAM FLOW DATA

Survey Stream Flow Data
Provisional Flows at U.S.G.S. Gaging Stations

Gage Station	Sampling Dates 1958	Discharge at Gage cfs	Reference Sampling Station
Patterson Creek of	9/11	7.9	B-1
North Branch Potomac	9/18	7.9	
near Headsville, W. Va.	9/25	11.0	
D.A. - 219 sq. mi.	10/2	8.5	
	10/9	8.5	
	10/16	8.5	
North Fork of South	9/10	35	A-3
Branch Potomac at	9/17	23	
Cabins, W. Va.	9/24	54	
D.A. - 314 sq. mi.	10/1	27	
	10/8	24	
	10/15	20	
South Fork of South	9/10	36	A-1
Branch Potomac near	9/17	23	A-7
Moorefield, W. Va.	9/24	27	
D.A. - 283 sq. mi.	10/1	20	
	10/8	19	
	10/15	18	
South Branch Potomac	9/10	115	A-2
at Petersburg, W. Va.	9/17	86	A-4
D.A. - 642 sq. mi.	9/24	139	A-6
	10/1	88	
	10/8	80	
	10/15	73	
South Branch Potomac	9/10	208	A-8
near Springfield, W. Va.	9/11	185	A-9
D.A. - 1,471 sq. mi.	9/17	140	B-2
	9/18	144	
	9/24	242	
	9/25	212	
	10/1	134	
	10/2	132	
	10/8	124	
	10/9	124	
	10/15	113	
	10/16	113	

Survey Stream Flow Data
Provisional Flows at U.S.G.S. Gaging Stations

Gage Station	Sampling Dates 1958	Discharge at Gage cfs	Reference Sampling Station
Cacapon River near	9/11	69	B-3
Great Cacapon, W. Va.	9/18	65	B-4
D.A. - 677 sq. mi.	9/25	86	
	10/2	68	
	10/9	63	
	10/16	58	
Little Tonoloway Creek	9/12	0.2	C-1
near Hancock, Md.	9/15	0.1	
D.A. - 16.9 sq. mi.	9/22	2.0	
	9/30	0.2	
	10/7	0.3	
	10/14	1.9	
Warm Springs Run			C-3
No gage.			
Sleepy Creek			C-4
No gage.			
Back Creek near	9/9	13	D-1
Jones Springs, W. Va.	9/12	12	C-5
D.A. - 243 sq. mi.	9/15	12	
	9/16	12	
	9/22	19	
	9/23	19	
	9/29	12	
	9/30	11	
	10/6	11	
	10/7	11	
	10/13	14	
	10/14	13	
Conococheague Creek	9/10	129	E-2
at Fairview, W. Va.	9/17	125	E-3
D.A. - 494 sq. mi.	9/24	188	E-4
	10/1	168	
	10/8	113	
	10/15	106	

Survey Stream Flow Data
Provisional Flows at U.S.G.S. Gaging Stations

Gage Station	Sampling Dates 1958	Discharge at Gage cfs	Reference Sampling Station
Opequon Creek near	9/9	85	D-2
Martinsburg, W. Va.	9/12	83	C-6
D.A. - 272 sq. mi.	9/15	79	
	9/16	80	
	9/22	100	
	9/23	83	
	9/29	70	
	9/30	70	
	10/6	63	
	10/7	64	
	10/13	58	
	10/14	60	
Antietam Creek near	9/10	126	E-5
Sharpsburg, Md.	9/15	119	E-6
D.A. - 281 sq. mi.	9/17	117	E-7
	9/22	200	C-8
	9/24	135	
	9/30	130	
	10/1	130	
	10/7	120	
	10/8	110	
	10/14	110	
	10/15	105	
Shenandoah River at	9/9	990	D-3
Millville, W. Va.	9/11	855	D-8
D.A. - 3,040 sq. mi.	9/16	778	
	9/23	855	
	9/29	601	
	10/6	650	
	10/13	560	
Catoctin Creek near	9/9	7.2	D-6
Middletown, Md.	9/16	5.7	
D.A. - 66.9	9/23	18.0	
	9/29	13.0	
	10/6	8.8	
	10/13	6.0	

Survey Stream Flow Data
Provisional Flows at U.S.G.S. Gaging Stations

Gage Station	Sampling Dates 1958	Discharge at Gage cfs	Reference Sampling Station
Monocacy River at	9/8	9.4	F-7
Bridgeport, Md.	9/15	5.0	
D.A. - 173 sq. mi.	9/22	154	
	9/30	36	
	10/7	15	
	10/14	11	
Monocacy River at	9/8	126	F-4
Jug Bridge near	9/15	111	F-5
Frederick, Md.	9/22	649	F-6
D.A. - 817	9/30	254	
	10/7	169	
	10/14	149	
Potomac River at	9/9	585	B-5
Paw Paw, W. Va.	9/11	530	
D.A. - 3,109 sq. mi.	9/18	352	
	9/25	536	
	10/2	370	
	10/9	357	
	10/16	375	
Potomac River at	9/9	733	C-2
Hancock, Md.	9/10	686	E-1
D.A. - 4,073 sq. mi.	9/2	623	
	9/15	573	
	9/17	504	
	9/22	565	
	9/24	790	
	9/30	469	
	10/1	469	
	10/7	413	
	10/8	413	
	10/14	351	
	10/15	368	
Potomac River at	9/9	2,250	D-7
Point of Rocks, Md.	9/11	2,020	D-5
D.A. - 9,651 sq. mi.	9/16	1,930	D-4
	9/23	2,130	
	9/29	2,250	
	10/6	1,780	
	10/13	1,570	

Survey Stream Flow Data
Provisional Flows at U.S.G.S. Gaging Stations

Gage Station	Sampling Dates 1958	Discharge at Gage cfs	Reference Sampling Station
Potomac River near	9/8	2,400*	F-1
Washington, D. C.	9/15	2,030	
D.A. - 11,560 sq. mi.	9/22	2,300	
	9/29	2,130	
	10/6	1,880	
	10/13	1,720	

*Figures do not include amounts diverted at Great Falls, (approximately 320 cfs).

PART III

APPENDIX V

LONG TERM BOD DATA AND
DEOXYGENATION VELOCITY CONSTANTS

V-1

Daily BOD Series (Average of Duplicates - ppm)

Days at 20° C	South Branch Station A-8	Potomac-Paw Paw Station B-5	Opequon Creek Station C-6	Antietam Creek Station E-7
1	0.70	1.55	1.88	0.33
2	1.17	2.57	2.92	0.57
3	1.48	3.48	3.50	0.80
4	1.67	3.75	3.95	1.00
5	1.82	4.17	4.30	1.15
7	2.08	4.85	4.83	1.85
9	2.32	5.54	5.72	2.36
11	2.59	5.95	6.19	3.05
Constant*	k_1=0.216	k_1=0.190	k_1=0.195	k_1=0.086

	Shenandoah River Station D-8	Potomac-Pt. of Rocks Station D-5
1	1.50	1.15
2	2.75	2.15
3	3.85	3.00
4	4.75	3.70
5	5.30	4.22
7	6.76	5.16
9	7.60	5.70
11	8.39	6.18
Constant*	k_1=0.074	k_1=0.081

* Computed by slope method

PART IV

REPORT ON BENEFITS TO WATER SUPPLY AND POLLUTION ABATEMENT FROM WATER STORAGE AND LOW - FLOW AUGMENTATION

ACKNOWLEDGMENTS

The conduct of a study of this type depends to a large extent upon the cooperation of other Federal agencies, State and local authorities, and industrial firms located in the study region. The cooperation provided by the below named agencies, industries, and individuals is gratefully acknowledged:

(1) the Allegany County, Maryland Commissioners, through Mr. Walker Chapman, County Engineer, for providing the necessary facilities for operation of Public Health Service mobile laboratory during the 1956 field survey;

(2) Mr. E. L. Mohler of the United States Geological Survey Office in Cumberland for providing stream discharge data as needed;

(3) Mr. Frank Powers and his staff at the Maryland Bureau of Mines Office in Westernport, Maryland, for information on the sources of acid mine drainage in western Maryland;

(4) Mr. Paul McKee, Director of the Maryland Water Pollution Control Commission for providing background information on problems in the region and pertinent data relative to the study;

(5) Mr. Glenn Hawkins, the regional representative of the Maryland Water Pollution Control Commission for providing liaison with representatives in the Luke-Cumberland vicinity;

(6) Mr. George L. Hall of the Maryland Department of Health for providing data concerning specific problems in the Cumberland area;

(7) Mr. E. S. Tisdale of the Interstate Commission on the Potomac River Basin for supplying information of importance in planning the study program;

(8) Mr. George M. Griffiths, Chief Sanitary Engineer of the West Virginia Pulp and Paper Company at Luke, Maryland, for providing invaluable information on the operation of the mill and plans for abating pollution - stream sampling data and information on plant waste were also made available from this source for use in the study;

(9) the Celanese Corporation of America, the Kelly-Springfield Tire Company, the Potomac Edison Company, and the Pittsburgh Plate Glass Company for furnishing plant operation information of particular value to the study; and

(10) the Washington District, Corps of Engineers for providing pertinent data relative to various reservoir sites in the region and the Department of Commerce Office of Business Economics for supplying population and economic data as required in the study evaluations.

INTRODUCTION

This report presents the results of an investigation of water uses, waste sources, and stream water quality in the North Branch Potomac River Basin and includes an evaluation of water supply and pollution abatement needs and the associated benefits that would accrue relative to proposed water storage and low flow augmentation in the region.

Request for the report was made by the U. S. Army Engineer District, Washington, Corps of Engineers on November 29, 1960, for the purpose of updating information and field data collected in 1956 and of developing additional information relative to future water supply and pollution abatement requirements.

The report outlines the major changes that have occurred since the 1956 PHS field survey. These include: (1) estimations of changes in stream water quality associated with a significant increase in pulp and paper manufacture at Luke, Maryland, coupled with recent completion of waste treatment works at this source, and at Cumberland, Maryland; (2) Department of Commerce studies which have enabled evaluations of future conditions and requirements.

The information on present and future water requirements are submitted in conformance with the Memorandum of Agreement of November 4, 1958, (between the Army and the Department of Health, Education, and Welfare) covering assistance to be provided by the Public Health Service to the Corps of Engineers in the implementation of the water supply programs of the Corps of Engineers, authorized under the Water Supply Act of 1958 (Title III, P.L. 500, 85th Congress).

Future water requirements for municipal and industrial use represent Public Health Service per capita water use estimates as applied to area figures developed from the Office of Business Economics regional economic evaluation by the Corps of Engineers in consultation with the Office of Business Economics and Public Health Service.

Future water quality aspects reflect the particular water uses and, where applicable, anticipated treatment measures that will be applied or required prior to returning the used water to the stream.

The areas in which project benefits to water supply and pollution abatement are expected to accrue are described and estimates of these benefits are given.

Factors relative to estimations made on the effect of recent changes on stream water quality are based on various parameters studied during the 1956 Public Health Service field survey, studies by Fuhrman in a report of the Interstate Commission on the Potomac River Basin and various other data as supplied by the West Virginia Pulp and Paper Company and Maryland Department of Health. By incorporating the characteristics of various parameters studied in past surveys in computations involving recent changes, an estimation of present and future stream water quality has been made possible.

On this basis also, suggested measures that could be applied to storage releases to obtain maximum control of pollution are given.

SUMMARY

1. The North Branch Potomac River Basin is next largest in size to the Shenandoah and South Branch Basins of the Potomac River Basin, and drains all of Allegany County and a portion of Garrett County in Maryland, parts of Somerset and Bedford Counties in Pennsylvania, and parts of Grant and Mineral Counties in West Virginia.
2. The population of the Basin at the present time is about 130,000, of which 66,500 persons reside in incorporated communities.
3. Based on Bureau of Census data and projections prepared by the Office of Business Economics, North Branch populations are expected to increase to 186,000 by 1985 and 269,000 by the year 2010.
4. The City of Cumberland, Maryland is the largest municipality in the region, with about 41,000 persons. It is expected that by the years 1985 and 2010, the populations of the metropolitan area of Cumberland will be 82,000 and 134,000, respectively.
5. Owing to the character and abundance of raw materials in existence in the Appalachian Mountain region of the North Branch, extensive industrial development has occurred and there are sufficient potential reserves to support greater development into the future.
6. Municipal water use in the Basin at the present time averages about 13.5 million gallons per day (MGD), of which 87.5 per cent is used for municipal purposes at Cumberland.
7. According to recent estimates, self-supplied industrial water requirements along the North Branch from Luke to Cumberland, Maryland average 151.5 MGD, of which 23.5 MGD are for industrial processing, 88 MGD for industrial cooling, and 40 MGD for steam-electric power production. About one-half of the total requirement is used twice throughout this reach.
8. It is estimated that the Evitts Creek supply to Cumberland (18 MGD capacity) will be inadequate prior to the year 1985 (20.5 MGD estimated for 1985), and that development of another source such as Evitts Creek, Wills Creek, or Patterson Creek to provide an additional 19 MGD will be required to meet 2010 demands.
9. Existing sources of water are considered sufficient to supply future municipal demands in the Bayard-Kitzmiller area, Luke-Keyser area, Frostburg and downstream Georges Creek area, upper Wills Creek area, and Patterson Creek area in the vicinity of Fort Ashby.
10. Water supply requirements for pulp and paper production in the Luke area without supplemental cooling exceed the dependable supply of the North Branch by 12 MGD at the present time, and are expected to exceed this supply by 84 MGD and 156 MGD by the years 1985 and 2010, respectively.

11. The Celanese Corporation, Kelly-Springfield Tire Company, and Pittsburgh Plate Glass Company take about 39.5 MGD from the North Branch for cooling and processing purposes. Requirements for similar purposes are expected to exceed the dependable supply of the North Branch by about the year 1995 at which time a source to supplement the North Branch supply would be required.

12. About 40 MGD are taken from the North Branch at Cumberland for steam-electric power production. Future water requirements for this purpose are estimated to be 202 and 365 MGD for the years 1985 and 2010, respectively.

13. Coal washery wastes and acid mine drainage enter the North Branch in the reach upstream from Luke, and pulp and paper mill waste, cellulose waste, and municipal wastes enter downstream from Luke.

14. Subsequent to the 1956 Public Health Service water quality survey, pulp and paper production capacity at Luke was increased from 400 to 800 tons per day and activated sludge treatment facilities were installed to treat the wastes. Compared with 1956 data, the estimated 5 day 20°C biochemical oxygen demand (BOD_5) loads discharged in the treated effluent to the North Branch from this source have been reduced from 47,000 to 16,000 pounds per day, and suspended solids from 106,000 to 34,000 pounds per day.

15. According to data collected in 1956, the Celanese Corporation plant, located on the North Branch between Cresaptown and Cumberland, discharges untreated wastes containing about 10,000 pounds of BOD_5 per day.

16. Subsequent to the 1956 field survey, the City of Cumberland provided primary treatment of municipal wastes by which it is estimated that waste loads have been reduced from 8,200 to 5,400 pounds BOD_5 per day.

17. Computation incorporating the reduced waste loads and minimum stream flows reveal that the condition of the North Branch has been improved from the standpoint of minimum dissolved oxygen concentrations. However, this water remains unsuited for use as a source of raw water for municipal and certain industrial processing purposes due to color, taste and odor producing materials, resin soaps, and caustic substances not removed from pulp and paper wastes by treatment.

18. The proposed objective for water quality management on the North Branch is to maintain the Class D, Interstate Commission on the Potomac River objective for dissolved oxygen (BOD_5 objective cannot be met with present knowledge of treatment) and development of a means of minimizing concentrations of persistent materials and nutrients that would be carried great distances downstream and well into the main stem of the Potomac River.

19. In order to maintain stream quality objectives and to prevent serious waste effects from extending far downstream into the main stem of the Potomac River, future industrial expansion and population

growth along the North Branch will necessitate the following: provisions for increased treatment capacity and efficiency at all waste sources; vigilance by industry to expand in-plant recovery systems in proportion to production increases; and greater waste assimilative and dilution capacity in the form of increased minimum continuous stream flows.

20. Development of supplemental water supplies will be required to meet future municipal and industrial water requirements along the North Branch Potomac River.

21. Without additional stream flow in the North Branch, supplemental cooling methods would be necessary to provide the cooling capacity required for industrial operations and thermal-power production.

22. Three reservoirs are proposed for the North Branch from which it is estimated that controlled minimum low flows up to approximately 410 cfs could be provided at Luke, Maryland.

23. The stream waters relative to the proposed Savage River reservoir are of excellent quality and contain no appreciable acid mine drainage or iron and manganese.

24. Although the waters at the proposed Stony River reservoir contain no measurable mineral acidity, the iron and manganese is of such magnitude during low flows, that, in order for the reservoir to be used as a source of water supply, facilities would be required to reduce these elements.

25. Waters relative to the proposed North Branch reservoir above Luke, Maryland are extremely acid during low flows and do not meet objectives for domestic raw water quality.

26. The Savage and Stony River impoundments would provide recreational attractions to the region, and if used to augment low flows in the North Branch, would produce decided reductions in acidity of stream water for use at Luke.

27. When impounded, the acid waters of the North Branch would be expected to damage submerged concrete and metal structures unless adequate protective measures are applied.

28. An impoundment on the North Branch would provide recreational attractions and waters containing less acidity for use at Luke than exist under present free-flowing low flow conditions.

29. Waters released from low level storage pools immediately upstream from Luke would have less seasonal temperature variation than that of the natural stream, and where used for industrial cooling purposes would contribute to improved condensing and cooling efficiencies.

30. The maximum low flow increase that could be developed from the proposed reservoirs, together with existing low flow and activated sludge treatment would control dissolved oxygen but would not provide sufficient dilution of colored wastes received in the North Branch at Luke to allow use of these waters for municipal supply purposes at Cumberland.

31. Waters stored in the Upper North Branch region with provisions for controlled low flow increases downstream by use of multi-level outlets would possess quality characteristics and assimilative capacity of significant benefit to downstream users.

32. No known practical conventional waste treatment method, by itself, exists which will provide a form of waste treatment comparable to that obtainable with conventional treatment supplemented by increased stream flow for control of dissolved oxygen, color, and persistent waste substances.

33. Benefits to water supply and pollution abatement by reduced acidity for the individual proposed reservoirs are given in Figures 30 and 31 of this report.

34. Benefits assignable to the individual proposed reservoirs for temperature reduction are shown in Figure 32.

35. Benefits applicable to flow increases for control of industrial waste effects, based on an estimated annual cost of $10,600 per cfs, are shown in Figure 35.

36. Benefits assignable to water storage and low flow increases for water supply exist in four locations and would apply to five different uses along the North Branch of the Potomac.

37. The annual benefits assignable to water storage for municipal use in the Luke area are estimated to be $10,600 per cfs and $7,100 per cfs in the Cumberland area.

38. Annual benefits assignable to water storage for industrial processing along the North Branch are estimated to be $14,000 per cfs.

39. Annual benefits assignable to water storage for industrial cooling and thermal power production are estimated at $1,800 per cfs for circulated water, and $14,000 per cfs for make-up water.

40. Additional water developed in the North Branch would be useful at several points for several purposes downstream from Paw Paw. Such uses include: municipal water supply at Hagerstown, Maryland, and Washington, D. C.; hydro-power or cooling uses to such electric power generating stations that are located, or will be located, along the main stem of the Potomac River; and pollution abatement in the Tidewater Basin of the Potomac in the Washington, D. C. area. Benefits to such uses have not been determined by this agency.

41. All benefits are limited to time periods and quantities of use and, therefore, are subject to appropriate discounting to present worth.

GENERAL

DESCRIPTION OF REGION

The North Branch Potomac River Basin is next largest in size to the Shenandoah and South Branch Basins with a drainage area of 1,328 square miles which constitutes 9.1 per cent of the entire Potomac Basin area and 13.3 per cent of the drainage area above Washington, D. C.

The basin lies in the extreme western portion of Maryland and in the middle northern section of West Virginia; it drains all of Allegany County and a portion of Garrett County in Maryland, parts of Somerset and Bedford Counties in Pennsylvania, and parts of Grant and Mineral Counties in West Virginia.

The main stem of the river follows a 98 mile easterly course converging with the South Branch to form the headwaters of the Potomac River near Paw Paw, West Virginia - 158 river miles above Washington, D. C. and 285 river miles above the mouth of the Potomac at Chesapeake Bay.

Throughout its length, the North Branch is characterized by a series of riffles and pools. It rises at an elevation of 3,180 feet and falls to about 930 feet at Luke, Maryland. From Luke to Cumberland, Maryland the average slope is about 11 feet per mile, and from Cumberland to the confluence with the South Branch the slope is about 5 feet per mile. Figure 13 shows the river reach surveyed and points at which samples were collected by the Public Health Service in 1956.

HYDROLOGY

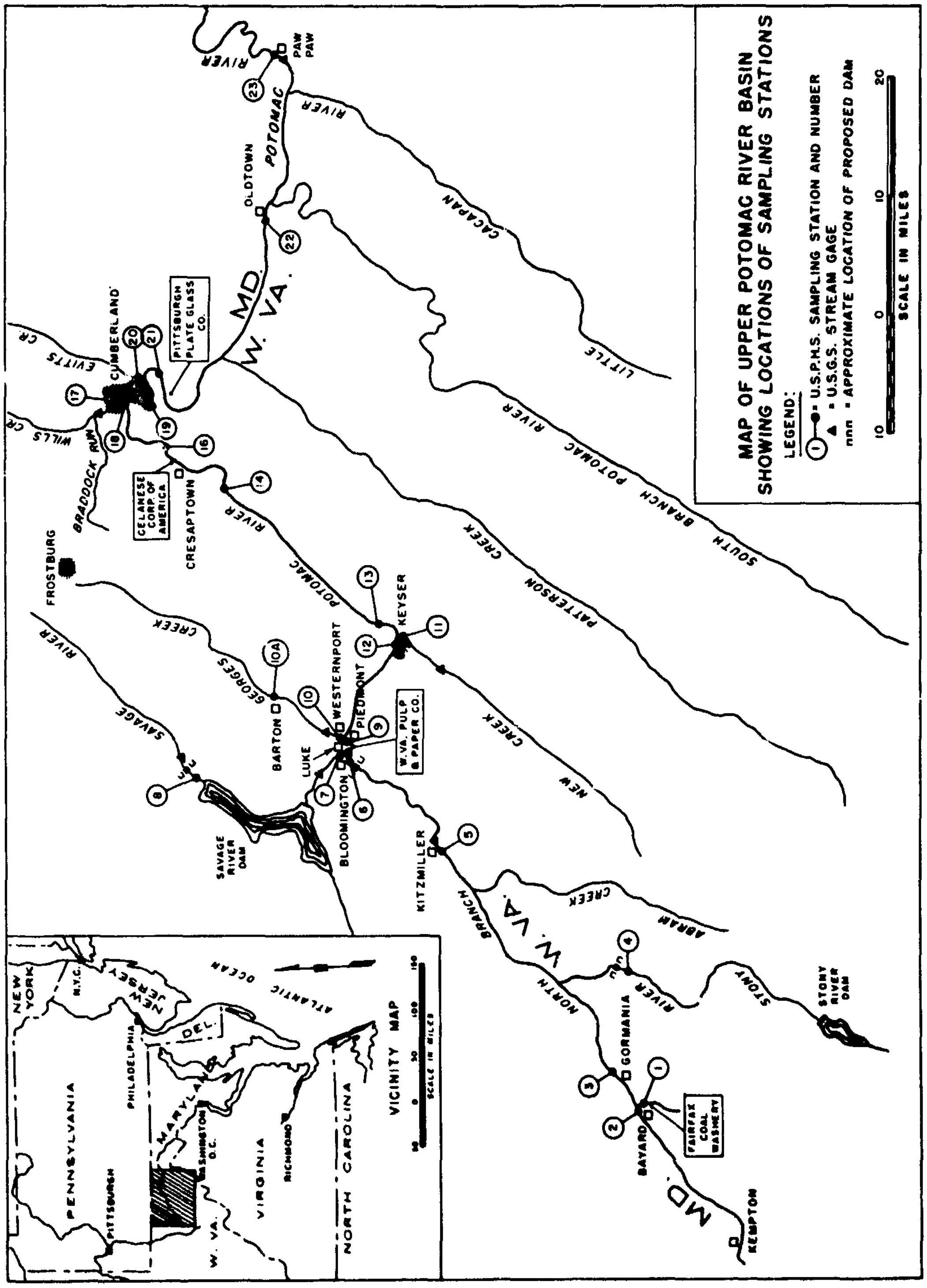
The average annual rainfall to the North Branch watershed is about 40 inches including snow accumulation of about 30 inches. Moisture runoff is very rapid in the region, producing wide extremes in stream flow.

From 28 years of stream gaging at Cumberland, the average flow of the North Branch has been 1,218 cfs with extremes of 38 cfs and 88,200 cfs. Flow variations as typified by gaging records for the years 1949-1950 are shown in Figure 14.

Since 1952, partial flow regulation has been accomplished through control of drainage from Savage River watershed. Control has been provided to a lesser extent since 1913 from a dam on Stony River which is owned by the West Virginia Pulp and Paper Company. The established minimum controlled low flow at Luke is 93 cfs.

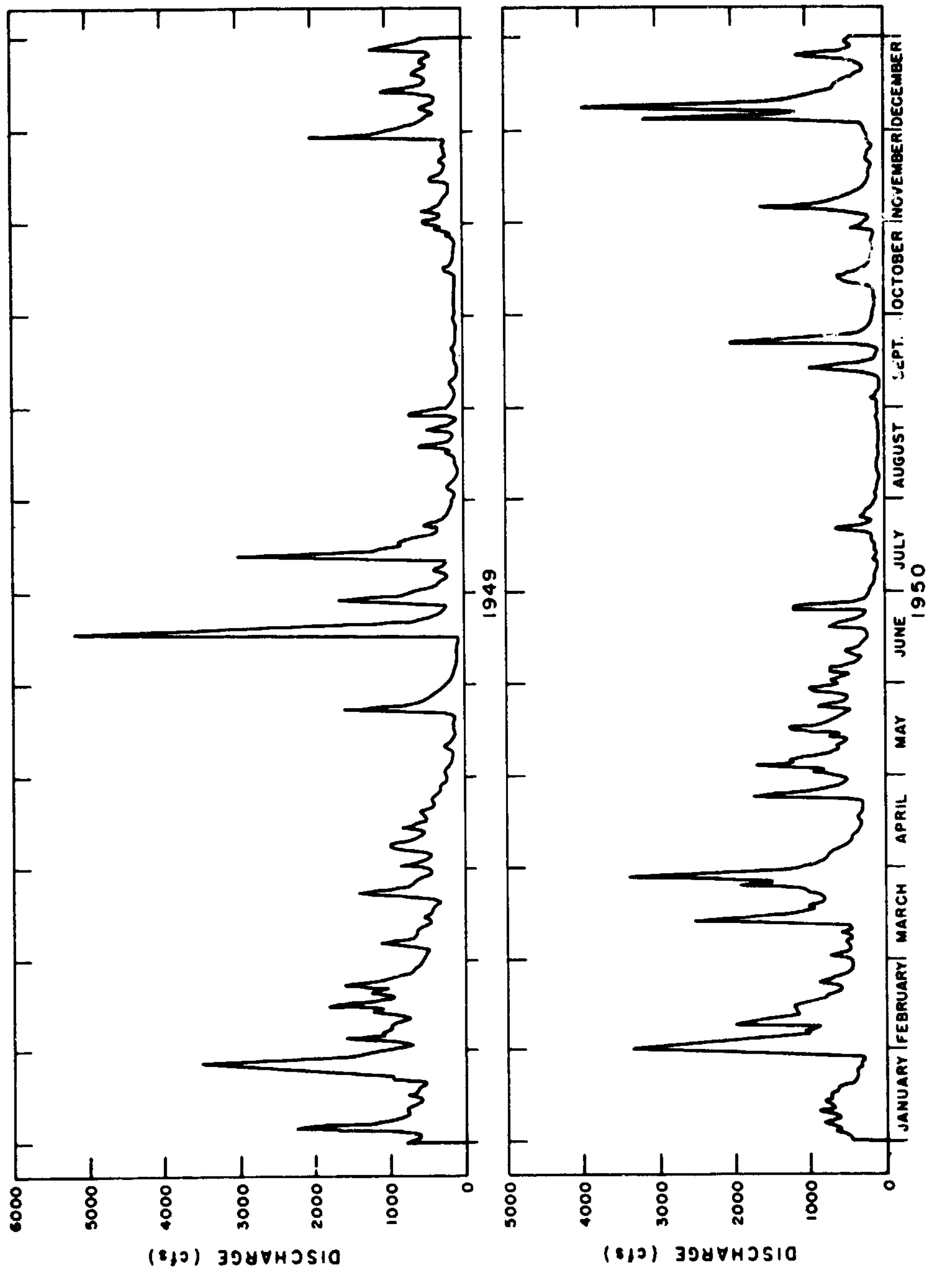
POPULATIONS - PRESENT AND FUTURE

Approximately 130,000 persons reside in the North Branch Potomac Basin, constituting about one-eighth of the Potomac Basin population excluding the Metropolitan Washington, D. C. area. About 66,400 persons,



MAP OF UPPER POTOMAC RIVER BASIN SHOWING LOCATIONS OF SAMPLING STATIONS
LEGEND:
= U.S.P.H.S. SAMPLING STATION AND NUMBER
= U.S.G.S. STREAM GAGE
= APPROXIMATE LOCATION OF PROPOSED DAM
10 0 10 20
SCALE IN MILES
POTOMAC RIVER
NORTH BRANCH
SOUTH BRANCH POTOMAC RIVER
LITTLE CACAPAN RIVER
PATTERSON CREEK
NEW CREEK
SAVAGE RIVER
GEORGES CREEK
BRADDOCK RUN
WILLS CR
EVITTS CR
ABRAM CREEK
STONY RIVER
STONY RIVER DAM
SAVAGE RIVER DAM
PAW PAW
OLDTOWN
CUMBERLAND
PITTSBURGH PLATE GLASS CO.
CELANESE CORP. OF AMERICA
CRESAPTOWN
FROSTBURG
KEYSER
WESTERNPORT
PIEDMONT
BARTON
LUKE
BLOOMINGTON
W. VA. PULP & PAPER CO.
KITZMILLER
GORMANIA
BAYARD
FAIRFAX COAL WASHERY
KEMPTON
MD.
W. VA.
VICINITY MAP
NEW YORK
N.Y.C.
NEW JERSEY
PENNSYLVANIA
PITTSBURGH
PHILADELPHIA
DEL.
MARYLAND
WASHINGTON D.C.
VIRGINIA
RICHMOND
NORTH CAROLINA
ATLANTIC OCEAN
SCALE IN MILES

FIGURE 13



HYDROGRAPH OF NORTH BRANCH POTOMAC RIVER AT BLOOMINGTON
FOR TWO TYPICAL YEARS OF RECORD

FIGURE 14

or 50 per cent of the North Branch population, reside in incorporated communities.

Based on Bureau of Census data and projections prepared by the Office of Business Economics for the Potomac River Basin, it is estimated that North Branch populations for the years 1985 and 2010 will be 186,000 and 269,000, respectively (see Table A-5).

By the years 1985 and 2010 urban population in the North Branch Basin will have increased to 102,000 and 160,000, constituting 55 per cent and 60 per cent of the basin population at these times, respectively. The largest population center in the Basin is Cumberland, Maryland where about 69 per cent of the urban population resides. By the years 1985 and 2010 the population in the Cumberland metropolitan area is expected to be 82,000 and 134,000, respectively. Table 15 shows the centers of population in the North Branch watershed and estimated population served by water supply and waste treatment facilities.

ECONOMICS - PRESENT AND FUTURE

The North Branch Potomac Basin is a highly developed region containing large water using and waste producing industries. The major industrial activities in the basin are: pulp and paper manufacturing, chemical manufacturing, cellulose products manufacturing, glass and rubber products manufacturing, railroading, steam-electric power generation, and coal mining.

Mining has been one of the primary means of livelihood in the past; many of the small communities grew up in the vicinities of mining operations. Many mines have been worked out, and the families remaining around these abandoned mines subsist primarily by farming.

In the Luke-Piedmont-Westernport area, the West Virginia Pulp and Paper Company is the primary source of employment; in the Cumberland area the Celanese Corporation, Kelly-Springfield Tire Company, Potomac Edison Company, and the railroads are major employers. Keyser, West Virginia is an important railroad maintenance depot. The most recent progress made in the region has been expansion of production capacity at the West Virginia Pulp and Paper Company, and opening of a Pittsburgh Plate Glass Company Plant near Cumberland.

The region has abundant natural resources of limestone, dolomite, glass sand, clay, hard and soft woods, and some coal and granite. The supply of surface and ground water is abundant in most localities. The climate and the terrain show good possibilities for recreational development.

According to an economic base study made by the Office of Business Economics, U. S. Department of Commerce, for the Appalachian Mountain region of the Potomac Basin, a significant expansion in industrial activity in the North Branch Basin can be expected in the next 50 years. Timber and coal reserves are of such magnitude that pulp and paper production can be expected to triple present production, and chemical and various commodity manufacturing activities will expand to more than two times present production.

TABLE 15

Centers of Population in the North Branch Watershed

Estimated 1960 Population*

Community	Served Water Supply	Served Sewage Treatment
On North Branch, Potomac River:		
Bayard, W. Va.	590	0
Kitzmiller, Md.	650	0
Luke, Md.	980	900
Westernport, Md.	4,200	3,500
Piedmont, W. Va.	2,700	2,400
Keyser, W. Va.	7,000	4,650
Cresaptown, Md.	900	0
Cumberland, Md.	41,100	43,000
Ridgeley, W. Va.	1,970	1,000
Total	60,090	55,450
Georges Creek Watershed:		
Frostburg, Md.	8,200	5,000
Midland, Md.	1,060	620
Lonaconing, Md.	2,750	1,880
Barton, Md.	700	480
Total	12,710	7,980
Wills Creek Watershed:		
Narrows Park, Md.	2,000	0
LaVale, Md.	4,260	0
Eckhart Mines, Md.	1,800	0
Mount Savage, Md.	2,100	0
Corriganville, Md.	600	0
Ellerslie, Md.	1,800	0
Hyndman, Pa.	1,350	1,320
Total	13,910	1,320
Grand Total	86,710	64,750

*At time of writing, exact figures for all communities were not available.

1956 FIELD SURVEY PROCEDURES

PRELIMINARY INVESTIGATION

The Potomac River Basin as a whole has been studied several times, and the Luke-Cumberland region has received particular attention from the Maryland Department of Health, the Maryland Water Pollution Control Commission, the Interstate Commission on the Potomac River Basin, and the several industries located there. Information obtained by these agencies was made available to representatives of the Public Health Service for their consideration and use in this study.

Review of these data prior to the 1956 field survey was made and a two-week reconnaissance of the region established the need for a detailed survey of the river. Factors requiring more specific information were: (1) the acid-mine drainage problem, (2) the control of low-flow conditions by the Savage River Dam, (3) changes in industrial plant operations, (4) planned modifications in the Cumberland sewage treatment system, and (5) a relocated dam at Cumberland. To supply this information, a sampling and analysis program was outlined which embodied procedures used in previous surveys and also included some additional tests to give a more complete picture of stream conditions.

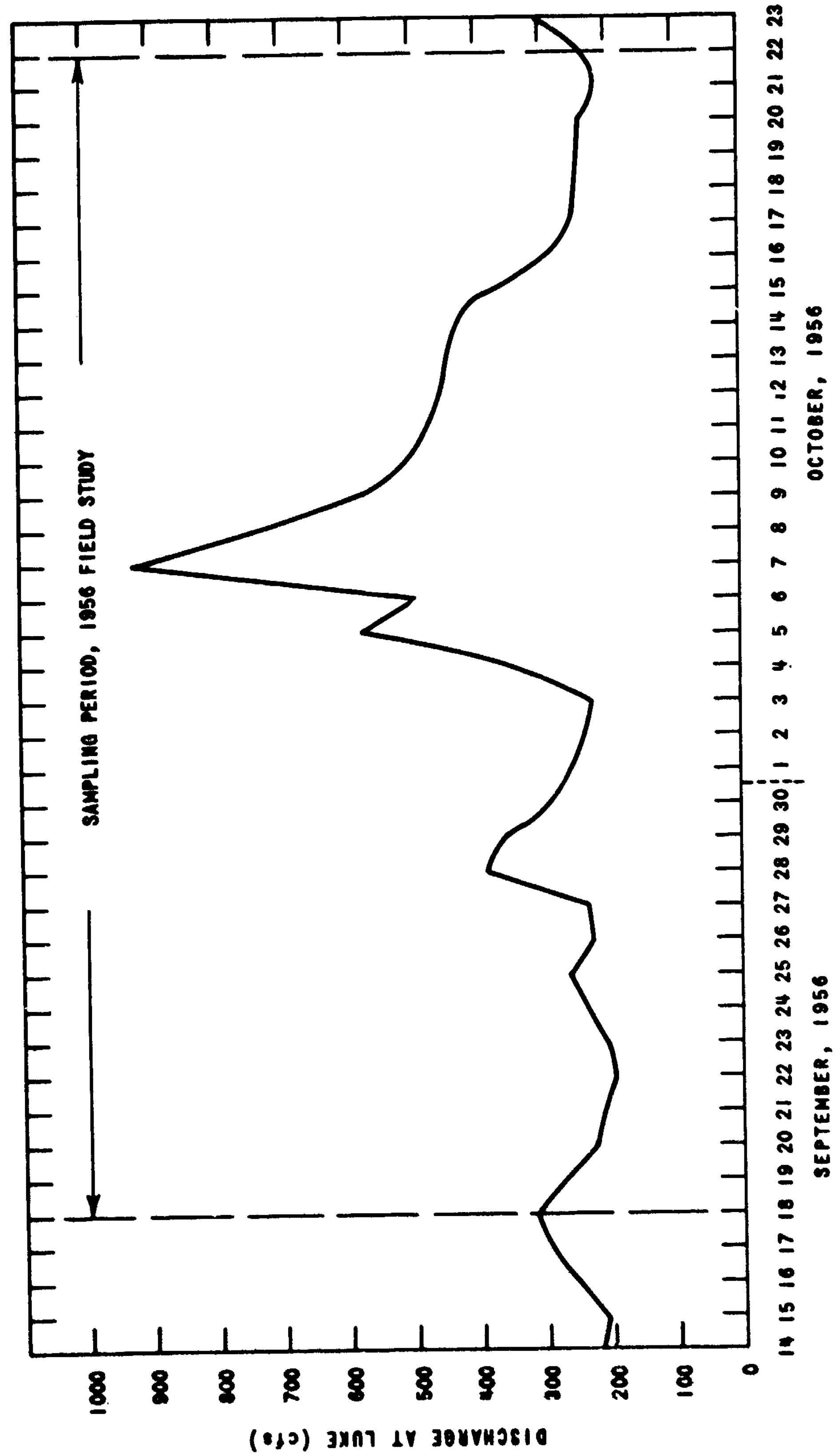
SAMPLING

Twenty-three sampling stations on the North Branch and its significant tributaries were selected, and a schedule was arranged for sampling all stations at least five times and the more significant locations a minimum of seven times. Provisions were also made for obtaining 24-hour composite samples at points which would be subject to fluctuations in waste load. The locations of the sampling stations are shown in Figure 13 and descriptions of these locations are given in Table 16.

A Sargent sampler was used, and all samples were collected by Public Health Service personnel. The samples for dissolved-oxygen determinations were fixed at the time of collection and titrated in the laboratory. Perishable samples were preserved by icing while being delivered to the laboratory.

Discharge measurements at most sampling stations were obtained from the U. S. Geological Survey. Figure 15 shows the variations in flow which occurred at the Luke gage during the survey. Proportionate fluctuations relative to these fluctuations occurred at other stations. Staff gages were erected at Sampling Stations 1 and 20; however, because the gage at Station 20 was destroyed by vandals, flows given for this location constitute estimates derived from only intermittent discharge measurements. A staff gage was also placed in the Cumberland sewage outfall for use in the composite-sampling program.

Composite-sampling procedures were applied at several locations. Composites in the Luke area were collected as follows: three composite samples from the stream above and below the paper plant on three different occasions; a sample at Station 9 taken every half hour for a 24-hour



FLOW IN THE NORTH BRANCH - SEPTEMBER AND OCTOBER, 1956

FIGURE 15

TABLE 16

Locations and Descriptions of Sampling Stations

Station No.	Stream	Town	Location	River Miles from Source	Drainage Area (sq. miles)
1	Buffalo Creek	Bayard, W. Va.	Highway Bridge, W. Va. Rt. 90	-	-
2	North Branch Potomac River	Bayard, W. Va.	Highway Bridge	11.1	-
-	North Branch Potomac River	Bayard, W. Va.	Confluence, Buffalo Creek	11.3	-
3	North Branch Potomac River	Gormania, W. Va.	Old Bridge, Downstream of US Rt. 50 Bridge	13.5	-
4	Stony River	-	Highway Bridge, US Rt. 50	-	-
-	North Branch Potomac River	-	Confluence, Stony River	19.4	-
-	North Branch Potomac River	-	Confluence, Abrams Creek	26.5	-
5	North Branch Potomac River	Kitzmiller, Md.	Highway Bridge, Md. Rt. 38	28.[illegible]	225
6	North Branch Potomac River	Bloomington, Md.	Highway Bridge	44.7	287
-	North Branch Potomac River	Bloomington, Md.	Confluence, Savage River	44.8	-
7	Savage River	Bloomington, Md.	Highway Bridge, Md. Rt. 135	-	-
8	Savage River	-	Savage River Road, Roadside Park above Lake	-	-
-	North Branch Potomac River	Luke, Md.	West Virginia Pulp and Paper Company	45.5	-
9	North Branch Potomac River	Westernport, Md.	Highway Bridge, Md. Rt. 36 Confluence, Georges Creek	46.9	407
10	Georges Creek	Westernport, Md.	Highway Bridge, Md. Rt. 135	Near Mouth	-
10A	Georges Creek	Barton, Md.	Highway Bridge, Md. Rt. 36 Below Barton	-	-
11	New Creek	Keyser, W. Va.	Highway Bridge, W. Va. Rt. 46	Near Mouth	46
12	North Branch Potomac River	Keyser, W. Va.	Highway Bridge, US Rt. 220	52.3	498
-	North Branch Potomac River	Keyser, W. Va.	Confluence, New Creek	52.7	545
13	North Branch Potomac River	-	Twenty-first Lane Railroad Bridge	54.1	550
14	North Branch Potomac River	Pinto, Md.	Highway Bridge	67.0	596
-	North Branch Potomac River	Amcelle, Md.	Calanese Corporation Plant	71.9	-
16	North Branch Potomac River	Fairgo, Md.	Cumberland Fairground Beyond far Paddock	73.2	613
17	Wills Creek	Cumberland, Md.	Highway Bridge, US Rt. 220	-	247
18	North Branch Potomac River	Cumberland, Md.	Highway Bridge, W. Va., Rt. 28	77.4	621
-	North Branch Potomac River	Cumberland, Md.	Confluence, Wills Creek	77.5	868
19	North Branch Potomac River	Cumberland, Md.	Wiley Ford Bridge, W. Va. Rt. 28E	79.6	875
-	North Branch Potomac River	Cumberland, Md.	Cumberland Sewage Outfall	80.9	-
20	Evitts Creek	-	Highway Bridge, Md. Rt. 51	-	-
-	North Branch Potomac River	-	Confluence, Evitts Creek	81.6	-
21	North Branch Potomac River	-	Railroad Bridge, Off W. Va. Rt. 28E near Airport	83.7	980
22	North Branch Potomac River	Oldtown, Md.	Toll Highway Bridge	96.7	1314
-	North Branch Potomac River	-	Confluence, South Branch	98.9	-
23	Potomac River	Paw Paw, W. Va.	Highway Bridge, Md. Rt. 51	107.5	3109

period; and samples taken concurrently at Stations 6 and 7 every 2 hours. Since river flows remained relatively constant during the compositing periods, no compositing in proportion to flow was deemed necessary.

Two 24-hour composites were collected from the Cumberland sewage outfall, each consisting of hourly samples composited in proportion to the rate of sewage discharge. In this instance a Sargent sampler was not necessary, since a dissolved oxygen determination was not required.

An eight-hour composite was taken at Station 1 while the coal washery was operating. Since the flow remained constant, the hourly samples collected permitted a uniform composite.

Samples were taken at Stations 14 and 16 every four hours for a 24-hour period and analyzed separately. This was done so as to measure the effect and extent of variations produced by fluctuations in flow and waste loads.

During the course of the survey about 2,500 tests were run on 191 samples. The daily sampling routes were each about 190 miles long. Samples arrived at the laboratory less than five hours after the first one had been taken, and all the analyses were started within the next few hours.

LABORATORY DETERMINATIONS AND SIGNIFICANCES

All the determinations except temperature were performed in the Public Health Service laboratory located at the Allegany County Garage in Cumberland. These analyses consisted of the following: dissolved oxygen (D.O.), biochemical oxygen demand (B.O.D.), chemical oxygen demand (C.O.D.), solids (total, settleable, suspended), color, pH, alkalinity or acidity, dissolved iron (ferrous and ferric), dissolved manganese, tannin and lignin, and sulfates. All tests followed the procedures outlined in Standard Methods for the Analysis of Water, Sewage, and Industrial Wastes, 10th Edition, except the iron determination, for which the dipyridyl method described in the Ninth Edition of Standard Methods was used.

The significance of each test in evaluating the sanitary quality of a stream is discussed below.

Temperature - The temperature of water controls the oxygen solubility and thus the saturation level of dissolved oxygen in the stream. The rate of bacterial growth is increased or diminished with higher or lower temperatures, respectively.

pH - pH is defined as the negative logarithm of the hydrogen ion concentration. The pH value indicates the relative acidity or alkalinity of a water, with the neutral point at pH 7.0. Values lower than 7.0 indicate the presence of acid salts and, from pH 7.0 to 14.0, the presence of alkalies or alkaline earth salts is indicated.

Dissolved Oxygen (D.O.) - Normally the amount of oxygen dissolved in water of a stream is limited by the saturation value (9.17 ppm at 20°C),

which is a function of water temperature, but in some cases, as a result of the photosynthetic action of some water plants, this value may be exceeded, causing "Supersaturation." The saturation value decreases with higher temperatures. To support fish and aquatic life and for natural aerobic purification of stream waters, dissolved oxygen must be present. The minimum quantity permissible is dependent on the quality of the water desired at a particular rate of stream flow. Dissolved oxygen must be present to prevent nuisance conditions associated with putrefactive decomposition of waste materials in a stream. Values below the saturation level are an indication of the presence of unstable organic substances which demand or utilize oxygen contained in the stream water. The gross effect of oxygen-demanding substances in a particular stream reach is measured in terms of the deficiency in dissolved oxygen content below the saturation value. The minimum desired level of dissolved oxygen in a river of satisfactory sanitary quality is usually considered to be 5.0 ppm.

Biochemical Oxygen Demand (B.O.D.) - The biochemical oxygen demand (frequently referred to as B.O.D.) of sewage, sewage effluents, polluted waters, or industrial wastes is the oxygen (in parts per million) required during stabilization of the decomposable organic matter by aerobic bacterial action. Complete stabilization requires more than 100 days at 20°C, but such long periods of incubation are impracticable in any but research investigations. Consequently a much shorter period of incubation is used. Incubation for 5 days at 20°C is recommended as the standard procedure. This recommendation was followed during the field study. Conversion of the data from one incubation period to another, or from one temperature to another, may be approximated.*

Coliform Group Organisms - This determination is a sensitive indicator of sewage pollution since it shows the approximate density of organisms that are normally found only in very small numbers in unpolluted streams. Coliform bacteria are normally present in the intestines of warm-blooded animals and are discharged in vast numbers in human feces, which constitute the main source of these bacteria in sewage. The coliform density is usually measured as most probable number (M.P.N.) per 100 millileters of sample. This method of reporting the results is commonly known as the M.P.N. Index.

Chemical Oxygen Demand (C.O.D.) - This test, otherwise known as Oxygen Consumed or O.C., serves as an index to the degree of pollution supplementary to the B.O.D. test. It is a measure of the quantity of carbonations material consumed by oxidation with strong oxidizing agents. The test does not differentiate between biologically stable and unstable organic matter.

Solids (or Residue) - The solids content of a sample is found by evaporating the sample to dryness and weighing the residue. The total solids are found by drying an unfiltered aliquot at 103-105°C. The result indicates the total solids present, both organic and inorganic.

*All B.O.D. data included in this report are based on 5-Day, 20°C B.O.D. unless otherwise noted.

Ignition of this residue at 500-600°C. will remove most of the organic material and water of crystallization, leaving the fixed solids as an indication of the amount of inorganic material present. During the ignition process some of the inorganic material undergoes chemical transformation which prohibits differentiation of the amounts of organic and inorganic material present. Sample filtration, followed by drying and residue ignition on the filter, results in the measure of suspended solids. Settleable solids are analysed by first allowing the sample to settle for a prescribed period of time followed by a measurement of the amount of material settled out. This test provides a basis for estimating the amount of material that can be expected to settle out in a short reach of the stream. Suspended solids data may be used to estimate the amount of material which is swept long distances downstream and which eventually may be deposited or dissolved depending on conditions in the stream.

Color and Tannins and Lignins - The causes of color in natural waters are due to dissolved or colloidal substances of vegetable origin extracted from leaves, peaty matter and other similar material. Colors consist of tannins, lignins, glucosides, derivatives of these substances, and iron and other substances. These materials are not necessarily harmful, but the color imparted to a stream must be removed to be acceptable for municipal and certain industrial processing purposes. Tannins and Lignins are a part of the coloring material. These substances may result from the partial decomposition of cellulosic material, or be produced by chemical means in certain industrial processes. The color these substances impart is very intense and persists for many miles in a stream. When a source of tannins and lignins is established, it is possible to trace, by this test, the extent to which these materials persist downstream. Both determinations utilize colorimetric techniques in which comparison of the sample with standard solutions is made.

Alkalinity and Acidity - The alkalinity of water, defined as its capacity for neutralizing acid, is usually due to the presence of bicarbonate and carbonate ions. In some waters hydroxide, borate, silicate, or phosphate ions may also contribute to alkalinity. Alkalinity is usually determined by titration with sulfuric acid to an end point of pH = 4.0. In this study all alkalinity and acidity titrations were performed electrometrically.

The acidity of water, which may be defined as the capacity for neutralizing base is normally associated with the presence of carbon dioxide, mineral and organic acids, and salts of strong acids and weak bases. Mineral acidity is determined by titration with standard base solution to an end point of pH = 4.5, and total acidity by titration to an end point of pH = 8.3. Acidity and alkalinity are reported as ppm $CaCO_3$ (Calcium Carbonate).

Iron and Manganese - These metals, when present in a water supply, can be precipitated in distribution systems causing corrosion of pipes

and discoloration of the water. Some iron and manganese are present in most natural waters and are usually present in large quantity in acid mine water. They are determined colorimetrically.

Sulfates - Sulfates are a common decomposition product of organic matter. They are also a product of reactions involving acid mine drainage. In water supplies sulfates have certain undesirable physiological effects in man. They are determined gravimetrically as barium sulfate.

PRESENTATION OF DATA

LABORATORY RESULTS OF THE 1956 FIELD SURVEY

The laboratory data on individual samples obtained during this survey are presented in Table A-1 of the appendix to this report.

The average of results at each sampling station are presented in Table 17. Where averages are based on less than the total number of samples taken at a given station, the number of determinations used to obtain the average is indicated in parentheses.

Averaged results for stations on streams subject to acid mine drainage are presented in Table 18. Data from streams not subject to this waste are presented for comparison.

DATA FROM OTHER SOURCES

1956 Study - Daily mean discharge measurements as provided by the U. S. Geological Survey for the period of the field survey are presented in Table 16.

In Table A-3 are presented hourly discharges at Stations 6, 7, 9 and 14 which correspond to composite sampling periods.

Data provided by the West Virginia Pulp and Paper Company for the period 1949-1955 on pH and acidity in the North Branch above the paper mill are shown in Table A-4.

1961 Study - Data on expected future development of the North Branch Potomac River Basin were obtained from the report, Economic Base Survey of the Potomac River Service Area, U. S. Department of Commerce, Office of Business Economics, October 31, 1960. In this report are presented summary population and employment data to the year 2010 for various sub-regions including the Appalachian Area in which the North Branch is located. From these data, the Corps of Engineers in consultation with the Office of Business Economics and Public Health Service have established various municipal and industrial growth rates on which to base anticipated future development potentials.

TABLE 17

Averages of Results
at Each Sampling Station

Station	Temp. (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/Day	C.O.D. (ppm)	C.O.D. #/Day	Solids (ppm) Total (w/o Set.S.)	Settleable	Total Fixed	Total Volatile	Total Suspended	Suspended Fixed	Suspended Volatile	Dissolved	Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm) Phen.	Total	Dissolved Fe (ppm)	Dissolved Fe++ (ppm)	Dissolved Mn (ppm)	Tannin (ppm)	Sulfate (ppm)
1	9.6	6.8	7.10	2.9		-		1930(6)	5900	815(6)	1115(6)	1010(6)	776(4)	036(4)	305(4)	45	3.6	(40.9)	(126)	-	-	-	-	-
2	9.9	33	9.56	0.64		-		440(5)	170(6)	230(5)	166(5)	6.9(3)	2(3)	4.9(3)	360(3)	15	3.5	(47.0)	(100.2)	-	-	-	-	-
3	16.0	30	9.08	0.44	87.3	-		300(5)	100(6)	204(5)	184(5)	21.1(3)	5.0(3)	16.1(3)	312(3)	19	3.5	(40.5)	(93.0)	-	-	-	-	-
4	10.6	36	9.48	0.84		-		152(5)	0(5)	96(5)	56(5)	16.3(4)	7.0(4)	9.3(4)	119(4)	42	6.5	-	(1.6)8.1	0.01(5)	0.08(3)	0.16(4)	-	1.2(3)
5	11.1	155	9.50	0.70	637	-		176(5)	67(6)	120(5)	56(5)	5.0(3)	1.5(3)	3.5(3)	120(3)	7	4.4	(2.2)	(16.5)5.4	0.72	0.09(3)	0.50	-	4.3(2)
6	14.3	276	9.55	1.2	979	-		224(5)	0(5)	172(5)	52(5)	6.5(4)	2.8(4)	3.7(4)	195(4)	6	4.2	(7.1)	(36.0)1.0	1.02	0.19	0.73(3)	-	-
6 - M	-	265	-	0.64	944	6.06		133	0	73	60	11.8	4.0	7.8	121	6	4.2	(4.0)	(16.0)2.1	0.42	-	0.42	0.28	6.1
6 - B	12.5	273	9.35	0.67	915	11.01	20000	185(4)	0(4)	105(4)	80(4)	14.2(4)	5.5(4)	8.7(4)	171(4)	5	4.3	(2.6)	(23.1)	1.09(2)	-	0.54(2)	0.40	6.6(6)
7	13.1	186	9.00	0.85	434	-		120(5)	0(5)	72(5)	48(5)	6.9(4)	2.7(4)	4.2(4)	96(4)	14	7.4	-	16.0	0.23(6)	0.02(3)	0.19	-	-
7 - M	-	114	-	0.51	317	5.35		106	0	53	53	7.5	0.4	7.1	98.5	13	7.1	-	15.1	0.12	0.05	0.48	-	1.32
7 - B	12	117	8.82	0.82	519	5.95	3760	100(4)	0(4)	65(4)	35(4)	13.8(4)	6.1(4)	7.7(4)	86(4)	12	7.3	-	18.7	-	-	-	0.34	1.05(4)
8	11	11.1	10.10	0.40	30.9	-		92	0	46	46	4.8	2.1	2.7	87	14	6.9	-	19.0	0.09	0.04	0.10	-	-
9	16	372	6.80	23.0	36400	96.2	170000	335	1100	155	180	74.7	27.5	47.2	260	100	7.3	9.3	46.3	0.95(1)	-	0.46(1)	5.6	6.3
9 - M	-	360	-	27.7	49400	85.8	144000	277	0	160	117	65.8	24.6	41.2	211	100	7.0	-	33.3	0.53	-	0.43	4.7	5.7
10	11	22	9.77	2.5	292	17.0	6370	723	50	510	213	57.1(6)	40.8(6)	16.3(6)	666(6)	6	4.3	(7.3)	(37.0)2.0	-	-	-	0.09	61.4(6)
10A	1	18	9.77	2.1		3.05(3)	570(3)	576(5)	0(5)	354(5)	172(5)	32.6(5)	17.8(5)	14.8(5)	493(5)	7	6.9	-	19.6	0.37	-	-	-	29.2(5)
11	11	16	9.46	1.6	350	7.27	1540	220(5)	0(5)	[illegible]	140(5)	27.3(5)	20.8(5)	6.5(5)	192(5)	12	7.7(6)	-	96.5(6)	-	-	-	-	-
12	14	437	6.25	14.8	34400	76.4	165000	[illegible]	800	154	137	55.7(6)	16.3(6)	39.4(6)	244(6)	64	7.4	2.0	36.4	0.78(4)	-	0.49(3)	4.6	-
13	15	403	6.76	13.4	34200	57.7	115000	267(6)	1600(6)	133(6)	133(6)	40.1(5)	13.3(5)	26.8(5)	224(5)	80	7.0	-	29.0(6)	-	-	-	-	-
14	16	600	6.10	7.3	16200	63.4	99000	218	0	144	74	34.7(8)	16.4(8)	20.3(8)	191(8)	81	7.1	-	37.3	1.11(6)	0.20(1)	0.57(6)	3.2(7)	-
15	17	446	6.30	9.7	25300	46.7	132000	272	0	220	52	46.2(4)	25.5(4)	20.7(4)	219(4)	69	6.7	-	37.0	-	-	-	-	-
17	14	85	9.91	5.3	2240	17.6	7860	312	0	256	56	83.9(4)	73.1(4)	10.9(4)	211(4)	17	7.2(4)	-	42.6(4)	0.17(2)	0.035(2)	0.52(2)	0.23(3)	-
18	17	504	3.38	7.6	20900	37.6	104000	235(4)	0(4)	190(4)	45(4)	22.6(3)	9.6(3)	13.0(3)	197(3)	69	6.9	-	46.4(4)	1.44(3)	0.24(2)	0.77(3)	2.91	-
19	17	520	6.88	4.1	11600	35.0	98500	299	0	168	60	40.4(4)	31.1(4)	9.3(4)	185(4)	67	7.0	-	48.0(4)	-	-	-	-	-
20	14	16	11.65	1.15	79	10.34	760	180(4)	0(4)	140(4)	40(4)	35.8(4)	29.8(4)	6.6(4)	144(4)	20	7.8(4)	-	175.5(4)	-	-	-	-	-
21	16	500	5.40	6.3	13700	33.2	102000	272	0	220	44	34.6(4)	24.5(4)	10.0(4)	195(4)	74	7.1	-	52.4(4)	1.24(3)	0.20(2)	0.70	2.6	-
22	17	730	6.48	2.5	10700	24.3	96300	264	0	196	64	24.2(4)	17.0(4)	7.2(4)	226(4)	51	7.2	-	53	0.93(3)	0.17(2)	0.39(3)	1.6	-
23	16	1030	7.93	1.4	8550	15.4	85300	200	0	145	55	16.8	14.2	4.7	141	60	7.3	-	55.4	0.62	0.08(1)	0.46	1.04	-

TABLE 18

Summary of Data from Regular Sampling Station
in Areas Subject to Acid Mine Drainage

Station	1	2	3	4	5	6	7	8	10	10A	17
Average:											
Temp. (°C.)	9	10	10	11	11	13	13	11	11	11	14
Discharge (cfs)	4.8	34	39	34	155	164	104	11	22	18	85
D.O. (ppm)	7.10	9.50	9.06	9.48	9.50	9.55	9.90	10.10	9.77	9.72	9.91
B.O.D. (ppm)	2.1	0.5	0.5	0.8	0.8	1.2	0.9	0.6	2.5	2.1	5.3
Color (ppm)	45	15	19	42	7	6	14	14	6	7	17
pH	3.6	3.5	3.5	6.5	4.4	4.2	7.4	6.9	4.3	6.9	7.2
Mineral Acidity (ppm)	40.9	47.0	40.5	0	2.2	7.1	0	0	7.3	0	0
Total Acidity (ppm)	128	100	93	1.6	16.5	38.8	-	-	37.0	-	-
Total Alkalinity (ppm)	-	-	-	8.1	5.4	1.0	18.0	19.1	2.0	19.6	42.6
Dissolved Iron (ppm)	-	-	-	0.8	0.72	1.0	0.23	0.09	-	-	.17
Dissolved Manganese (ppm)	-	-	-	0.16	0.50	0.73	0.19	0.10	-	-	.52
Solids:											
*Total (ppm)	1830	420	388	152	176	224	120	92	723	528	312
Settleable (ppm)	5.1	0.2	0.2	0	0.1	0	0	0	0	0	0
Total Fixed (ppm)	415	230	204	96	120	172	72	48	510	356	256
**Total Suspended (ppm)	1610	6.9	21	16	5	8.5	6.9	4.8	57	33	84

* Average based on seven determinations
** Average based on three to five determinations

The evaluations presented in subsequent sections of this report have incorporated these and certain other pertinent data as described. Recent contacts were made with officials at the West Virginia Pulp and Paper Company to obtain data on latest production and treatment plant operation objectives.

CRITERIA FOR DETERMINING PROJECTED WATER REQUIREMENTS FOR WATER SUPPLY IN THE POTOMAC RIVER BASIN

GENERAL

The protection of public health through the provision of a safe water supply has long been a matter of primary concern to the public health profession and has been a significant contributing factor to the high health standards of the nation. However, the problem of providing adequate amounts of safe potable water has become increasingly difficult due to the pyramiding water demands of a rapidly expanding population. Furthermore, the resulting increase in waste flows has caused a gradual degradation in the quality of the nation's waters. While improved methods of treatment and disinfection of both wastes and water have served to maintain the quality within tolerable limits, the progress in pollution abatement and water treatment has not kept pace with this population growth and industrial expansion.

The familiar problems of pollution by bacteria, organic matter, and chemicals of known toxicity and behavior have been further intensified and complicated by problems of mineral enrichment due to water re-use and by new types of contaminants associated with our chemical and atomic age. The effects of these newer contaminants on water treatment processes and on the human consumer are largely unknown. The deficiencies in knowledge and the prospect of even greater quantities of yet more complex pollutional materials reaching our surface waters emphasize the urgency of intelligent water quality management.

It is recognized that water for human consumption holds the highest priority of all water uses. The increased demands on quantity by an increasing variety of uses has also brought about many conflicts which can be solved only by intelligent and long-range management practices. Unfortunately, practically every water use results in some degradation of quality. As the supply becomes more critical and conflicts in use increase, water quality is assuming increasing importance.

Where alternate sources are available it is desirable to reserve the highest quality water available for domestic use and to satisfy other lower priority demands with waters of lesser quality. In areas of limited supply the ultimate water requirement can be met only by water re-use. Thus, dependence must be placed upon improved and

more effective methods of water and waste treatment in order to maintain the highest possible standards of quality for human consumption. In such instances, however, every effort should still be made to reserve a sufficient quantity of high quality natural water for domestic use before it flows on to supply other less critical demands.

It is sound planning to utilize highest quality water for highest priority uses, and the protection of this quality against irreversible and potentially hazardous degradation must be practiced to the fullest extent possible.

The magnitude of increased water use for all major purposes in the United States during the 55 year period 1900-1955 was from 40.2 billion gallons to 262.0 billion gallons per day.[1] The development of American agriculture, industry, rural life and metropolitan growth has been based primarily upon the availability of an abundant and economical water supply of suitable quality. By 1975, water use in the United States for all major purposes is expected to be 453.2 bgd, or an increase of 191.2 mgd from 1955.

Following is a tabulation of water uses by categories as estimated for the United States:

WATER USES IN THE UNITED STATES
(1900-1957 - U. S. Dept. of Commerce)
(Billion Gallons Per Day - Average)

Use Category	1900	1955	1975
Irrigation	20.2	119.8	169.8
Rural	2.0	5.4	7.2
Public	3.0	17.0	29.8
Industrial & Miscellaneous	10.0	60.0	115.4
Steam Electric	5.0	59.8	131.0
All Uses	40.2	252.0	453.2

Studies made on public water supplies indicate that there were about 4,000 supplies serving 30 million people in the year 1900; 17,500 supplies serving an estimated 111 million people in 1955; and by 1975 it is expected that 148.8 million people will be served by public water supplies in the United States.[2] Such supplies furnish water for domestic, commercial and industrial purposes within their areas of distribution. The studies on water use (Picton and Levie[2]) incorporated surveys made by the American Water Works Association, the U. S. Public Health Service, and the Water and Sewerage Industry and Utilities Division of the Business and Defense Service

1 - Picton, W. L., "Water Use in the United States, 1900-1975, Dept. of Commerce, Business Service Bulletin - 136, Jan. 1956.

2 - Picton, W. L., and A. T. Levie, "Public Water Supplies Capital Investment Values, 1942-1955-1975, Dept. of Commerce, Business Service Bulletin - 146, April 1956.

Administration, U. S. Department of Commerce. From these sources of information on water uses and Census Bureau figures on population it is found that in addition to increased water demands by direct increases in population, the per capita daily average use of water in the United States is on the increase. National municipal per capita water use in 1954 was 147 gallons per day. In view of past trends it is reported that the per capita daily average municipal use is expected to average 190 gpd by 1965 and to reach 200 gpd in 1975.

From a study of 58 municipal systems operated by the American Water Works Service Company, Inc., it was revealed that residential sales of water per service for the years 1939-56 increased fairly uniformly at the rate of about two per cent per year.[1] It was also indicated that metered residential sales increased with rising family income. Although data on peak demands were incomplete, available data indicate that maximum daily demands attributed to lawn sprinkling, air conditioning, and refrigeration resulted in demands ranging from 139 and 177 per cent of the typical week-day use. These peak demand rates, according to the Task Committee report, correspond to additional rates of 140-277 gpcd. The available data showed that the relationship between maximum and average day demands during the period 1939-1956 remained constant.

CRITERIA FOR DETERMINING FUTURE MUNICIPAL AND SANITARY DISTRICT WATER REQUIREMENTS

Because provision of a continuously adequate and potable water supply is basic to public health and the general well-being of the population and economy, planning for future water demands and uses require the utmost of care and application of a reasonable degree of optimism. This is especially true when planning for requirements fifty years in advance or to the year 2010 as is the objective of this evaluation.

The municipal or public water supply system referred to in this investigation is defined as that facility serving all urban and suburban residences, commercial establishments, and small industrial users located within areas of reasonable distribution. A Sanitary District water supply system is defined as that facility which serves or may serve unincorporated small town uses, commercial or small industrial users outside of municipal limits, and rural non-farm residences located within areas of reasonable distribution from the facility.

Water requirements for municipal and district uses are given by areas within the drainage basin as governed by centers of population and location with respect to possible reservoir storage sites. Requirements within each area are determined from county population figures projected to the year 2010 by the Office of Business

1 - The Task Committee, A.W.W.A., "Study of Domestic Water Use," J.A.W.W.A., November 1958.

Economics, Department of Commerce. Since not all county populations would be served by central water supplies, a division is made into those populations expected to be served by municipal and district supplies, and those expected to have individual supplies. The municipal and sanitary district population figures are then multiplied by an appropriate daily per capita water use figure to obtain the total requirement (see Rationale, page 27 of this report). In the event that water storage is required, both daily average and maximum daily average water requirements are given for use in determining reservoir storage capacity; that is, the former value for supplies taken directly from storage and the latter for supplies taken downstream.

Based on studies of per capita water uses and apparent trends toward increased per capita demands in the future, the added annual unit increase in daily per capita municipal and district water uses is taken as 1.5 per cent of the 1960 per capita figure. Maximum daily uses are obtained by adding 50 per cent of the 1960 average gpcd as a constant to the future increases in average gpcd.

The county populations provided by the Office of Business Economics are divided into two categories; namely, farm and non-farm populations. The non-farm populations are further divided into three groups--rural residential, small towns, and urban. Municipal and district water requirement evaluations concern mainly the non-farm population groups although it is known that farmers in certain areas haul significant amounts of water by tank truck from municipal systems. Area water requirements for municipal and district purposes include all urban populations up to 85 per cent of the rural residential population (depends on availability of ground water for individual well supplies), and certain small towns whose populations are expected to exceed 1,500 by the year 2010.

RATIONALE - MUNICIPAL WATER SUPPLY DEMAND

The demand for municipal water supply is created by a number of special uses; i.e., domestic, commercial, public, fire, and industrial. The number of diversity of commercial business establishments, attractiveness to tourists and conventions, community habits, public policy with respect to civic duties, and size and type of industries within any city are peculiar to that city under consideration only. As a consequence, the municipal water demand computed on per capita basis can be expected to vary among cities. Very often for purposes of developing overall data on municipal water demand, writers have grouped cities by population brackets to determine unit water use. While this method furnishes a general idea of overall quantity of municipal demand, an engineer developing estimates of future water needs of a specific city would look primarily to the characteristics of the city under consideration.

The rates of municipal water use are affected by the size of the community, its location, habits and standard of living, availability of water, quality and cost of the water, the existence of sewers, extent and use of meters, pressure maintained on the distribution system, and other variables.

It should be pointed out that municipal uses are largely non-consumptive and it can be expected that about 90 per cent of the municipal demand will be returned to the water courses.

Domestic Use - The water used by the individual as a beverage is a very small quantity. The water used by the individual for such purposes as bathing, laundry, toilet, kitchen, car wash and yard use are much larger demands for domestic purposes.

In projecting domestic water use, it is reasonable to believe that the standard of living will get progressively higher and that individuals will install water-using devices for convenience and comfort. Based on existing water-using devices only, and considering apartment occupants, a use of over 80 gpcd can be foreseen. For individuals occupying houses, a larger use of 110 gpcd can be expected.

Commercial Use - This use is a composite of demands by many diversified business establishments such as hotels, motels, restaurants, shopping centers, bowling alleys, auto repair garages, auto service stations, and laundries. The type and number of such establishments will vary among communities and is a function of population as well as many other considerations of community character. A city such as Washington, D. C., which attracts tourists, conventions, and other visitors, would probably have a large water demand based on this consideration only. For instance, a restaurant will require about 9 gallons of water per meal served,[1] and a motel or hotel will have a demand of 70 gallons of water per day per guest.[1]

Observations made by others show from 10,000 gallons per acre per day for a shopping center to over 90,000 gallons per acre per day for a complex mercantile district of a large city.

Public - Water used for public purposes includes street washing, park fountains and lawn watering, public buildings, public schools, and public hospitals. The rate of use will vary in communities according to the character of the city and public policy reflecting degree of civic pride. This water is often supplied to the city without remuneration to the municipal waterworks.

Fire Protection - Protection against fire is an important function of a municipal waterworks. The total yearly quantity used for this purpose is small, but during a fire the rate of use is so large as to be the deciding factor in determining the design of pumps, storage capacity, and distribution mains in most communities.

1 - Thesis for Masters Degree - Phillip Searcy, U.S.P.H.S.

Industrial Use - This use varies greatly according to the nature of the manufacturing and each case must be udied individually. Observations made by others show that the industrial use ranges from zero to over 80 gpcd, based on the entire population of a city.

Waste - While waste is not a use, it is certainly a consideration in developing a water supply adequate for the community, and appears within the gross per capita demand figure. Waste results from leakage aggravated by high pressures on the distribution system and careless or willful users.

Summary - In planning future water needs of an area, it is believed that the designer should consider requirements for public health and convenience primarily, and that estimates to meet these foreseeable needs should be generous. A rigid interpretation of historical records has in the past almost always resulted in an under-designed water system. In Committee Print No. 7 of the Select Committee on National Water Resources, page 11, it was stated that the present 147 gpcd of average municipal use could conceivably increase to about 185 gpcd in 1980 and to 225 gpcd in the year 2000, with a possible leveling off thereafter.

It is believed that the best estimate of municipal demand can be developed by utilizing the historical record of each community and projecting increased use at a rate of 1.5 per cent per year. Existing variations of the several uses as previously discussed are already built into historical records. It is recognized that an upper limit of per capita water use will develop; and beyond that limit, use might be considered wasteful. Based on present knowledge, this upper limit will probably be in the range of 225-250 gpcd. Estimates of future demand are tempered by this judgment factor.

CRITERIA FOR DETERMINING FUTURE INDUSTRIAL WATER REQUIREMENTS

Industrial water requirements are complicated by many factors affecting variability. Every product requiring water in its manufacture utilizes differing quantities and qualities of water and even identical product manufacture sometimes differs in amounts of water used. The prime uses of water in industry are for cooling or condensing and for product processing. Significant losses of industrial water by evaporation or consumption in the product can occur and frequently water can be re-used within the plant. Experience has shown that without ample water for industrial use, area development can be greatly curtailed. Water is one of the prime requisites in attracting new industry to a site whether it be required for product manufacture or merely for sanitary use and fire protection. Since the ultimate objective of industry is increased production to meet promoted product demands, ample water must be available to satisfy continuously expanding needs.

Industrial uses of water in the United States during the 55-year period 1900 to 1955 increased six-fold, or from 10 billion gallons per day in 1900 to 60 billion gallons per day in 1955. On the basis of this increase and various growth stimulating factors, estimates for the 20-year period 1955 to 1975 indicate that industrial uses will nearly

double the 1955 figure. It is also noted that industrial uses of water in the United States were more than three times the municipal uses in 1900, 3.5 times the municipal uses in 1955, and are estimated to exceed the growing municipal uses estimated for 1975 by more than a factor of four.

The increase in industrial water use predicted by Picton (20-year period, 1955 to 1975) is an increase of 200 per cent. Woodward shows increases in industrial uses of 220 to 400 per cent for the 25-year period of 1955 to 1980.[1] Differences in estimated future uses of industrial water by various authors appear to reflect viewpoints on water uses by newly established plants. Conservative estimates include only increased uses by existing industries.

Industrial water, for purposes of this investigation, is defined as water obtained from sources other than municipal or district supplies for use in the manufacture of a product or products including in-plant uses for processing, cooling, and sanitation purposes. In cases where industrial water requirements include uses in the steam generation of electricity, this use is shown separately because such plant sites are limited to only certain areas.

Total area industrial water requirements are computed to the year 2010 by expanding 1960 industrial uses at an annual rate of increase consistent with economic evaluations prepared by OBE, Department of Commerce for the Potomac Basin. Depending upon economic growth and predicted population figures, annual industrial water requirement rates of increase for various areas may range from 2 to 8 per cent of 1960 uses (Maximum increase of 400 per cent by the year 2010). Areas where known industrial development is taking place but for which industrial water requirements are not shown, reflect types of industries requiring relatively small quantities of water, the quantities of which are reflected in municipal and district water requirements.

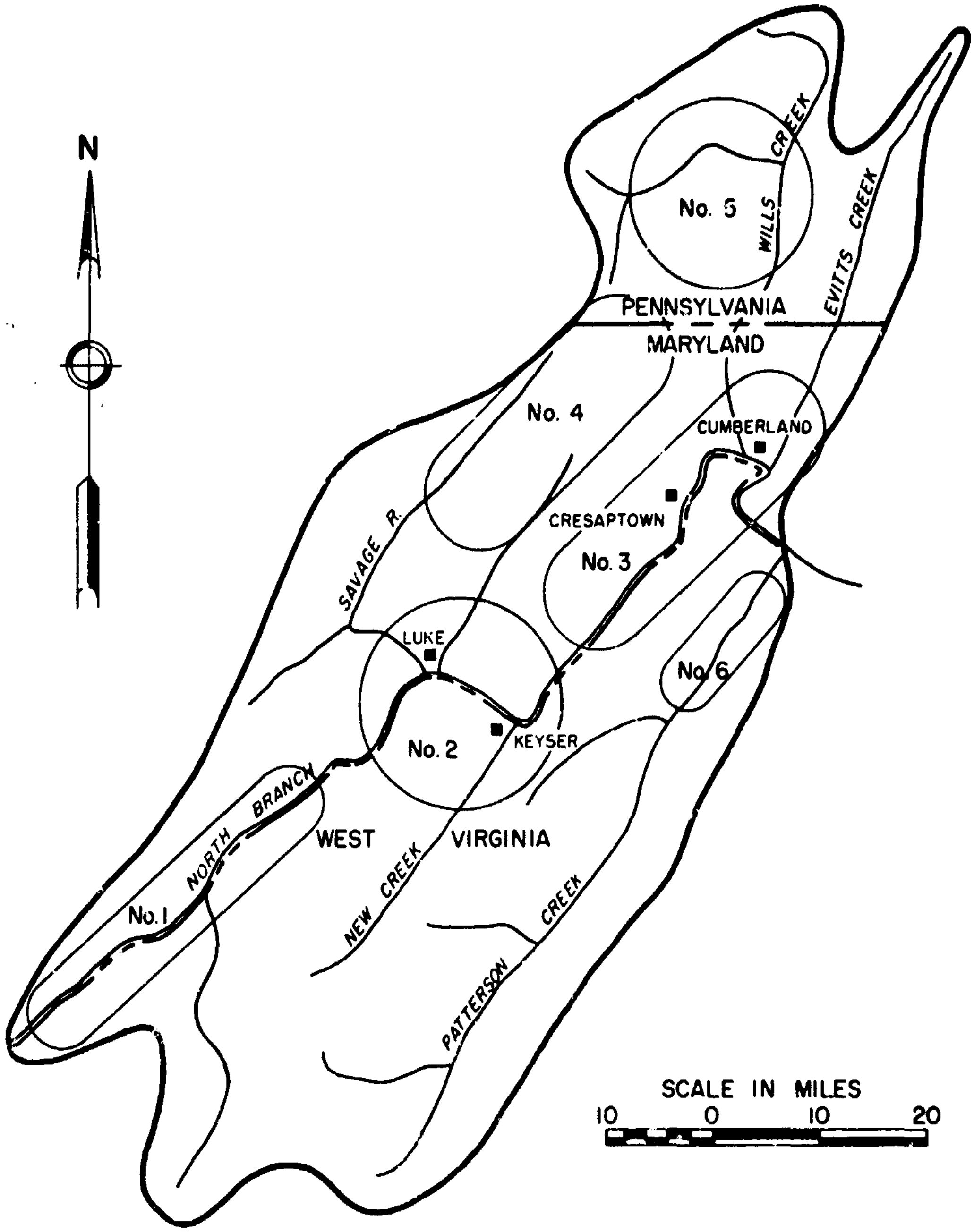
WATER USES, SOURCES AND REQUIREMENTS - PRESENT AND FUTURE

There are 12 central water supplies serving about 75,000 persons and 5 self-supplied industrial supplies serving major needs in the North Branch Potomac Basin.

The major industrial uses of water exist along the North Branch from Luke to Cumberland, Maryland, a distance of approximately 35 river miles.

Municipal water use in the Basin averages about 13.5 million gallons per day (MGD) of which approximately 95 per cent is obtained from surface sources with the remaining taken from wells and springs. Figure 16 shows the major areas to which these data pertain (also see Tables A-6 and A-7).

1 - Woodward, D. R., "Availability of Water in the United States with Special Reference to Industrial Needs by 1980," Industrial College of the Armed Forces, Washington, D. C., 1956-1957.



NORTH BRANCH POTOMAC RIVER BASIN

WATER SUPPLY AND WASTE SOURCE SUB-DIVISIONS

FIGURE 16

Self-supplied industrial water requirements along the North Branch, from Luke to Cumberland, average 151.5 MGD of which 23.5 MGD are for industrial processing, 88 MGD for industrial cooling and 40 MGD for steam-electric power production. About one-half of the total requirement is used twice throughout this reach.

The City of Cumberland (located in subdivision 3), the largest municipal water user in the Basin obtains water from two municipal reservoirs on Evitts Creek, having a maximum capacity of 18 MGD. The present average use at Cumberland is 11 MGD with a maximum use of 14.5 MGD.

Municipal water uses of much smaller magnitudes than that used at Cumberland exist in the Luke area and the headwater areas of the North Branch and along several tributary streams. About 0.11 MGD is used in the Bayard-Kitzmiller area (subdivision 1); 0.7 MGD in the Luke-Keyser area (subdivision 2); 1.1 MGD in the Frostburg and downstream Georges Creek area (subdivision 4); 0.6 MGD along the Wills Creek watershed (subdivision 5); and about 0.17 MGD along Patterson Creek at Fort Ashby (subdivision 6). Except for Frostburg, which obtains about one-half (0.5 MGD) of its water from wells, and Fort Ashby, which obtains water from wells, the supplies in these areas are obtained from surface sources.

With the population growth and per capita water demands (see Table A-8) expected for the years 1985 and 2010, the municipal water requirements at Cumberland including the industrial demands for city water are expected to be 20.5 and 37 MGD, respectively. On this basis, the entire capacity of the Evitts Creek supply would be in use prior to 1985, and by the year 2010 the demand would exceed the supply from this source by about 19 MGD (see Figure 17).

The municipal water demand for 1985 and 2010 in the Bayard-Kitzmiller area will be about 380,000 and 980,000 gallons per day (0.38 and 0.98 MGD), respectively; in the Luke-Keyser area 1.9 and 4.6 MGD, respectively; in the Frostburg and downstream Georges Creek area 2.3 and 4.9 MGD, respectively; in the Wills Creek watershed 1.6 and 3.7 MGD, respectively; and along Patterson Creek at Fort Ashby 420,000 and 960,000 gallons per day (0.42 and 0.96 MGD), respectively. It is expected that existing sources of water in these areas will be sufficient to supply the increased future demands that are anticipated (see Figures 18, 19, 20 and 21).

The West Virginia Pulp and Paper Company at Luke, Maryland, uses 60 MGD from the North Branch which is essentially the entire dependable supply of the stream. Of this amount, 21 MGD are for processing and 39 MGD are for cooling when in combination with cooling towers. The cooling water requirement without cooling towers is 51 MGD which together with the process water exceeds the dependable stream flow by 18 cfs (dependable stream flow - 93 cfs).

The Celanese Corporation, Kelly-Springfield Tire Company, and Potomac Edison Company at Cumberland, Maryland, together take 77 MGD

from the North Branch for cooling purposes and about 3.5 MGD from the City of Cumberland for processing and sanitary use. The Pittsburgh Plate Glass Company at Cumberland obtains approximately 2.5 MGD from the North Branch for processing.

By the year 1985, with production of 1,600 tons of pulp expected, the water requirements for pulp and paper in the vicinity of Luke will be 144 MGD of which 42 MGD will be for processing and 102 MGD for cooling purposes. By the year 2010, with production of 2,400 tons of pulp, the total requirement will be 216 MGD of which 63 MGD will be for processing and 153 MGD for cooling. Should continued use be made of North Branch waters for domestic purposes in the Luke-Keyser area as supplied from industrial facilities, an additional 4.6 MGD would be required, making the total additional requirement for industrial and municipal purposes in the Luke area 160.6 MGD for the year 2010 (see Figure 22).

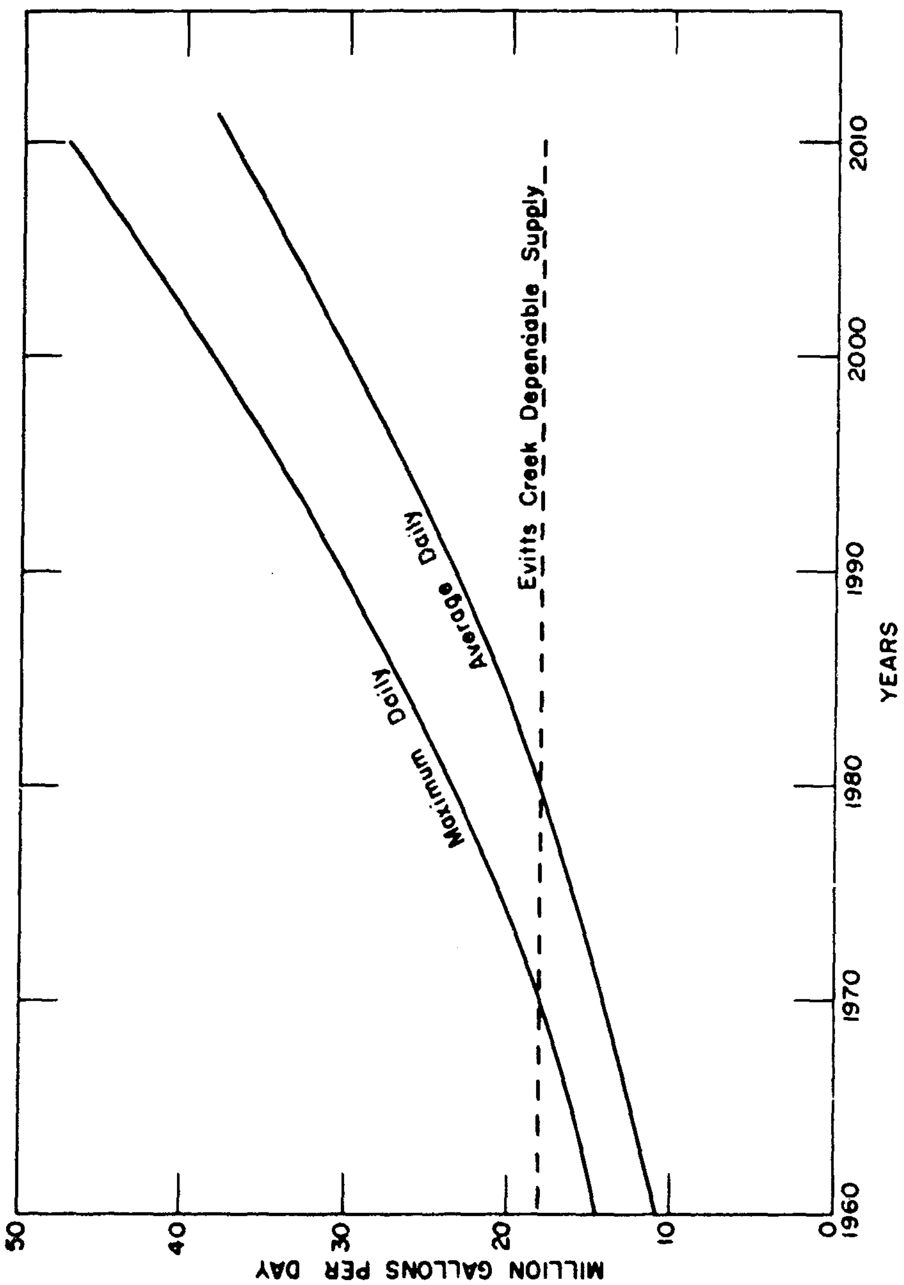
The demand for water from the North Branch by self-supplied chemical and commodity producing industries located in the vicinity of Cumberland, Maryland, will be 63.9 MGD by 1985. Of this amount, 3.9 MGD will be needed for processing and 60 MGD for cooling. By the year 2010 the requirement for these uses will be 87.8 MGD of which 4.8 MGD will be needed for processing and 83 MGD for cooling. Since these industries are presently able to tolerate the quality and utilize the quantity of waters returned to the North Branch from the pulp and paper operation at Luke, it is expected that upon meeting future requirements for both industrial water and waste treatment combined with flow augmentation at Luke, the industrial processing and cooling water requirements at Cumberland will be fulfilled (see Figure 23). The demand for high quality process water from the City of Cumberland by these industries will be 5.4 MGD for 1985 and 6.8 MGD by the year 2010. These requirements are included in the total requirement presented for municipal water at Cumberland.

The water requirements for steam-electric power production for the years 1985 and 2010 are 202 MGD and 365 MGD, respectively without employing supplemental cooling methods (see Figure 24).

WATER QUALITY AND WASTES - PRESENT AND FUTURE

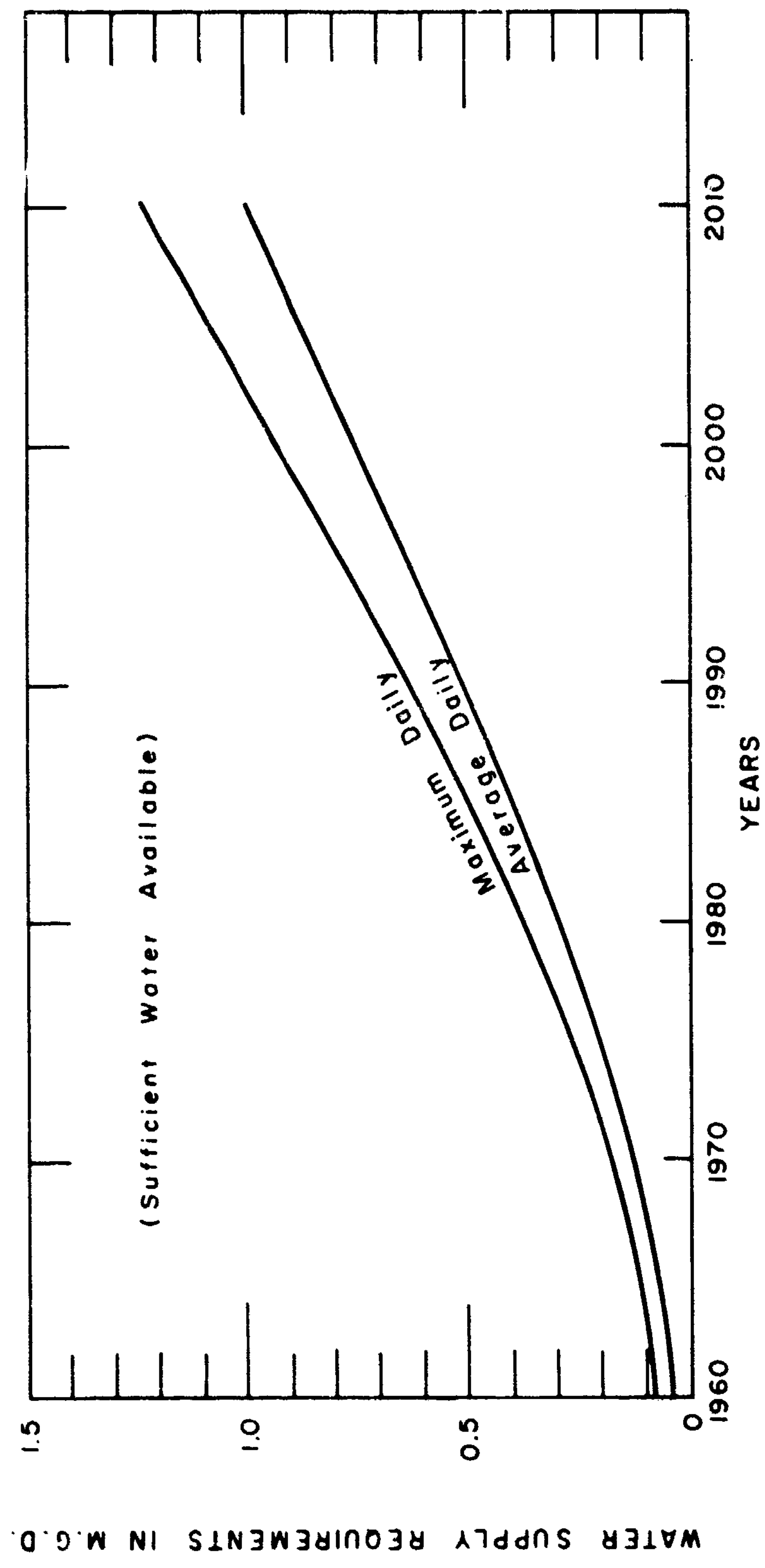
Because of the large quantities of acid mine drainage and municipal and industrial wastes received, North Branch waters are not used for municipal purposes except at Luke, Maryland, where acid water is treated by the West Virginia Pulp and Paper Company for local domestic use. The acid condition of North Branch waters is alleviated at Luke by neutralization with alkaline pulp and paper mill wastes.

According to stream survey results of 1956, Georges Creek, which discharges to the North Branch downstream from Luke, was found to be highly acid as a result of mine drainage. Contrary to reports on the acidity of Wills Creek discharging to the North Branch at Cumberland, survey results showed no measurable amounts of acid in the waters near the mouth of this creek (see Figure 25).



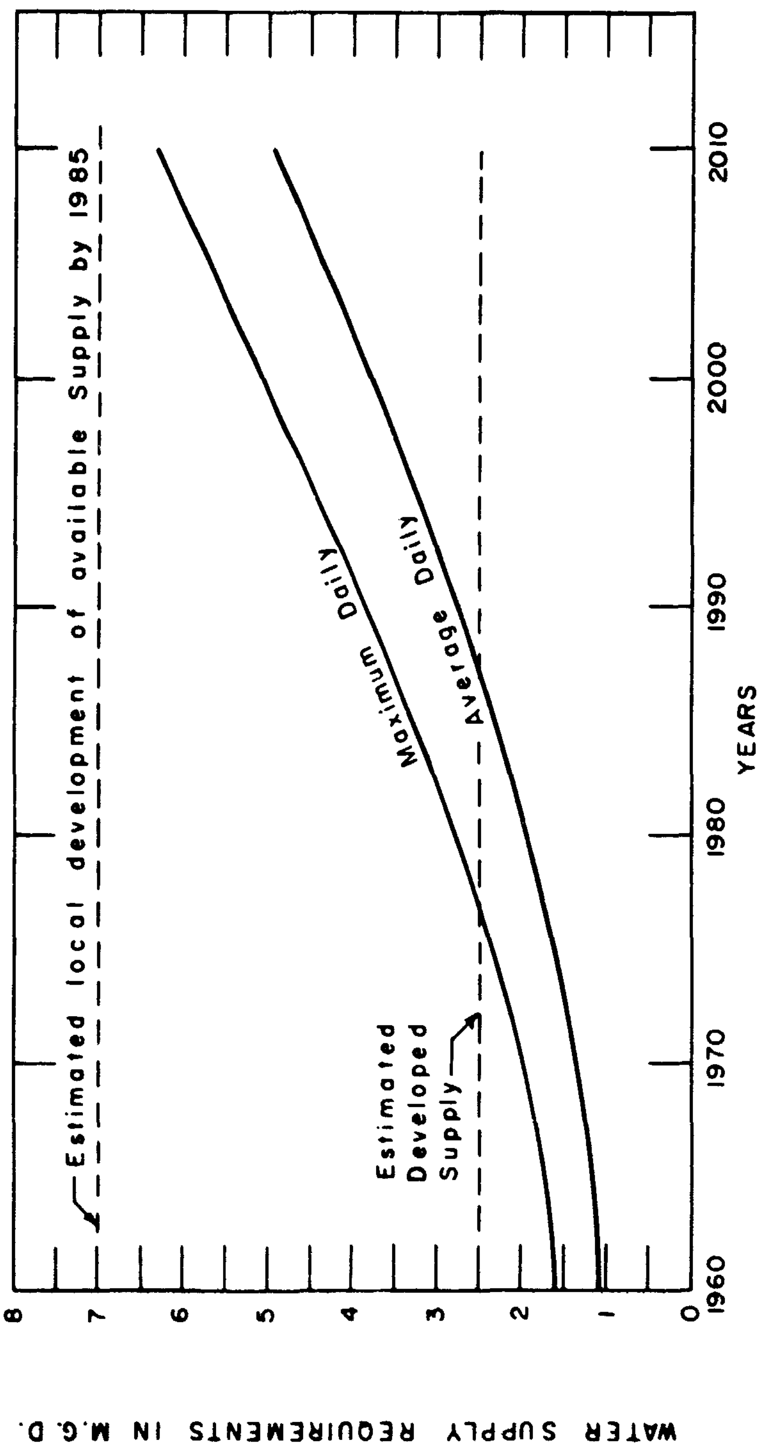
NORTH BRANCH POTOMAC RIVER
MUNICIPAL WATER SUPPLY REQUIREMENTS
CUMBERLAND AREA
SUBDIVISION NO. 3

FIGURE 17



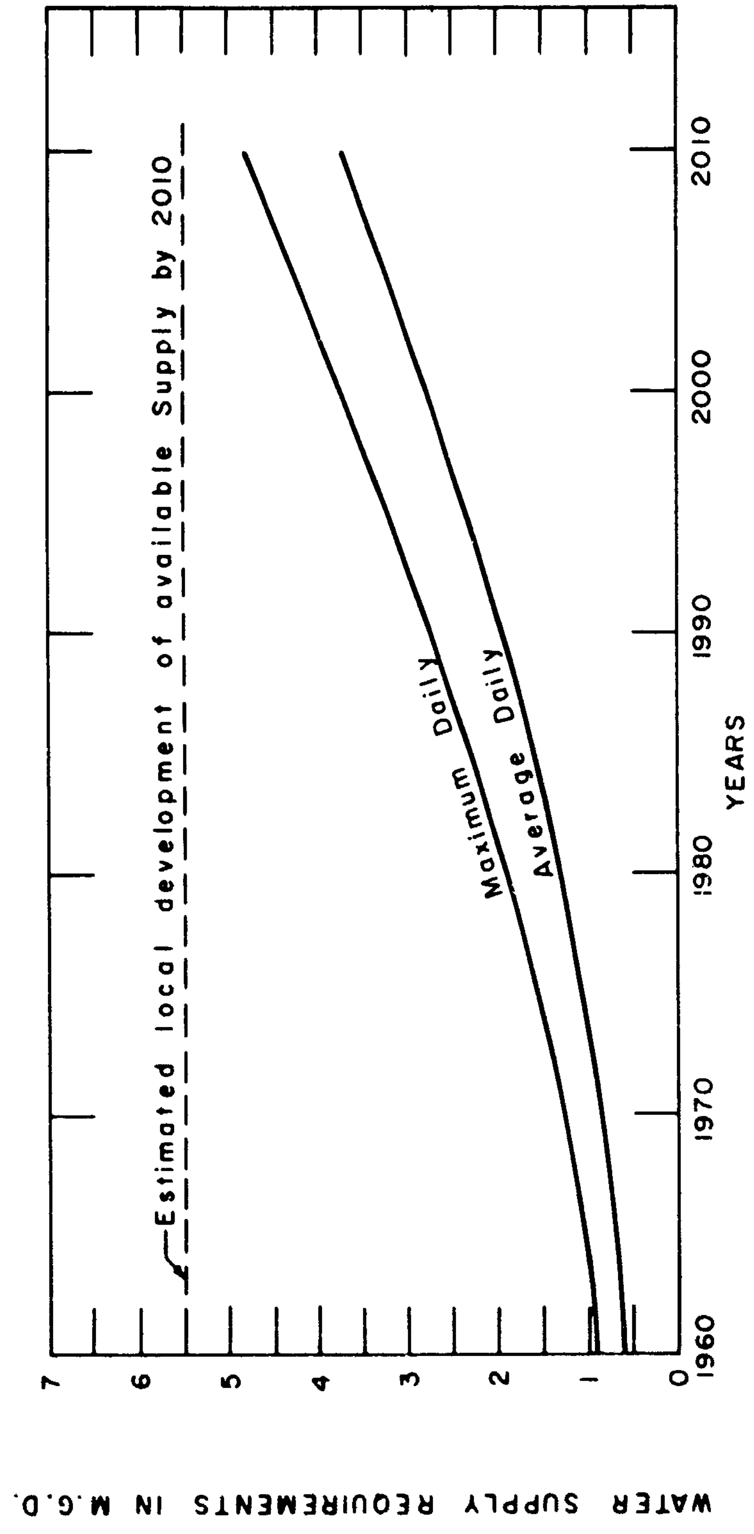
NORTH BRANCH POTOMAC RIVER
MUNICIPAL WATER SUPPLY REQUIREMENTS
BAYARD–KITZMILLER AREA
SUBDIVISION NO. 1

FIGURE 18



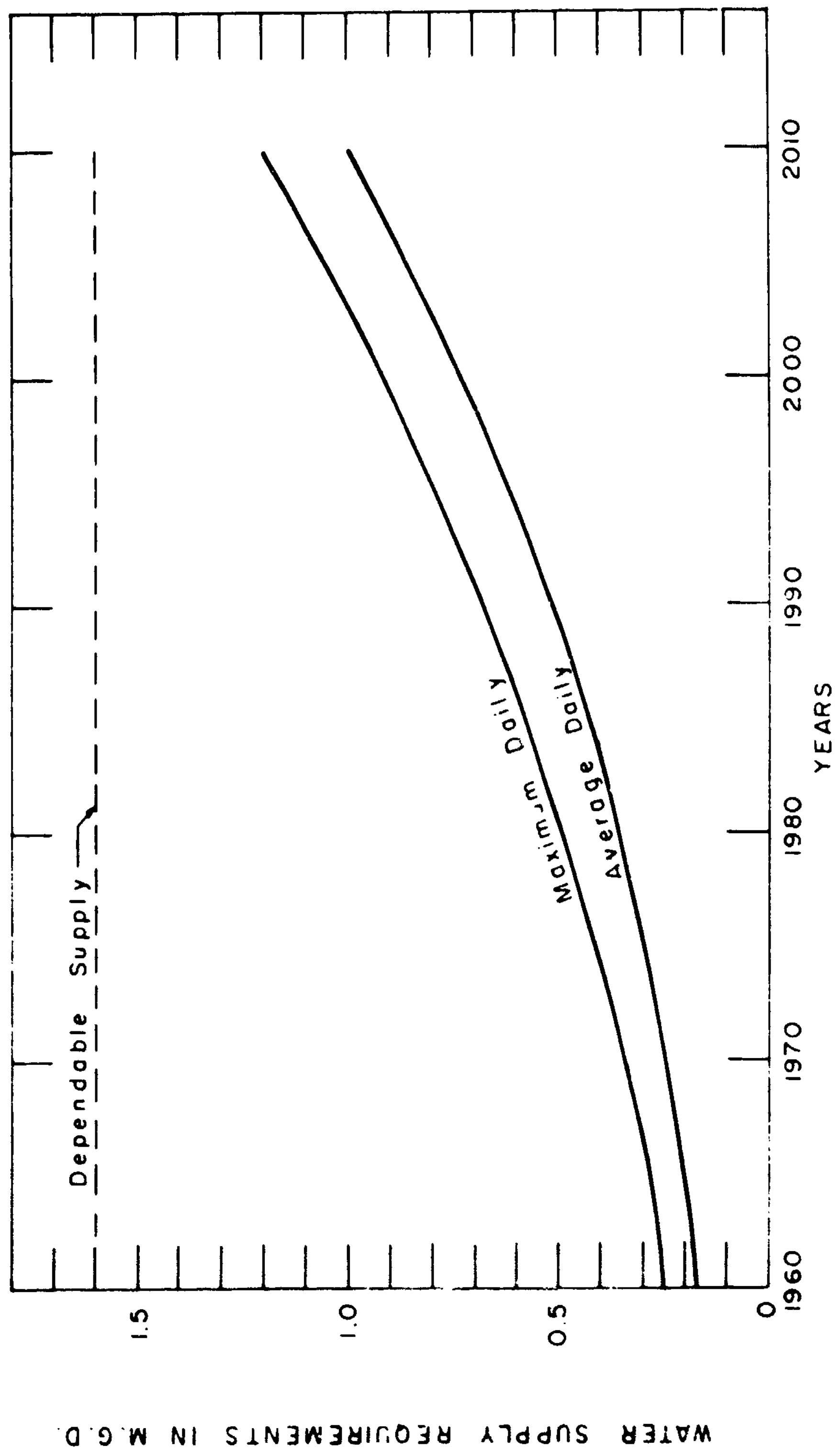
NORTH BRANCH POTOMAC RIVER
MUNICIPAL WATER SUPPLY REQUIREMENTS
UPPER GEORGES CREEK AREA
SUBDIVISION NO. 4

FIGURE 19



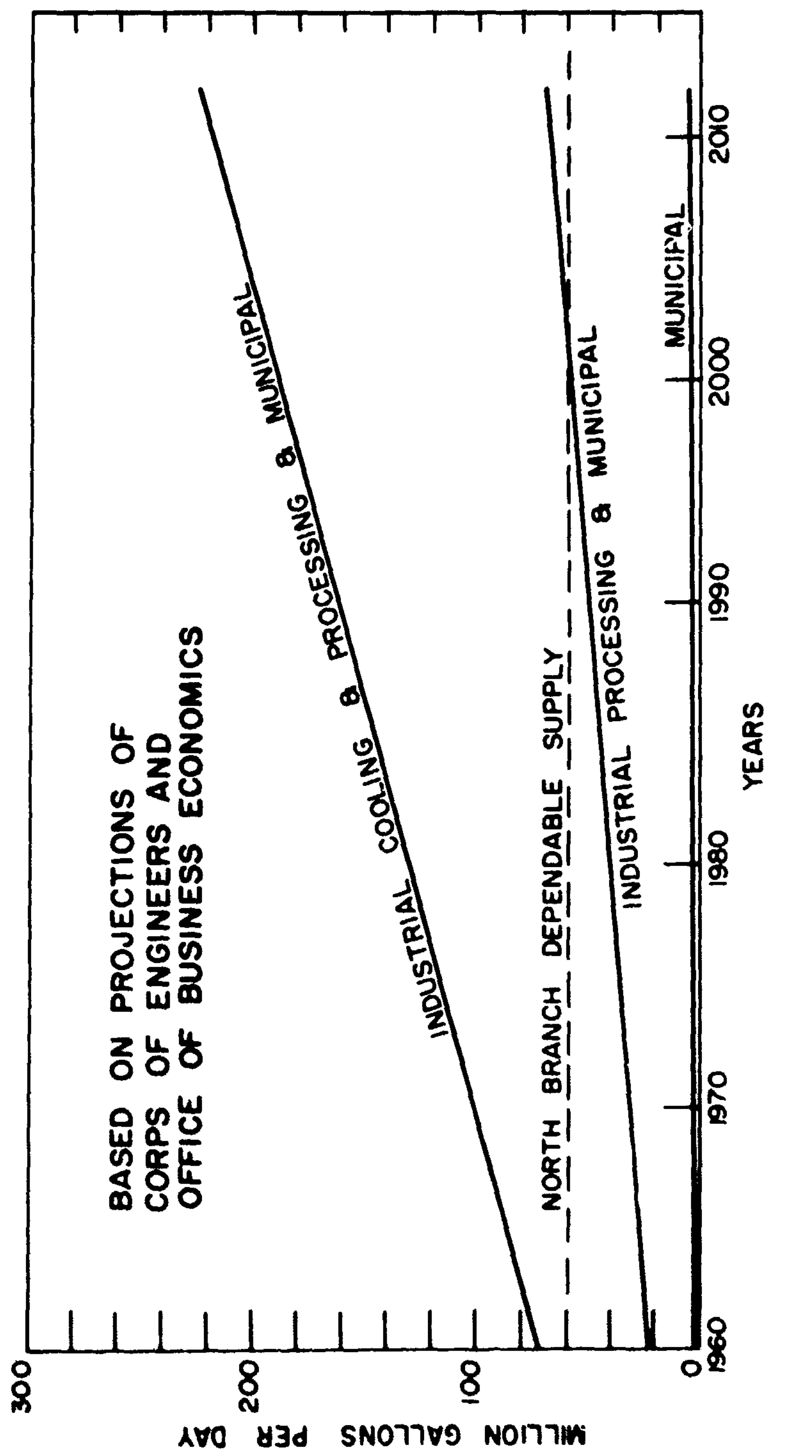
NORTH BRANCH POTOMAC RIVER
MUNICIPAL WATER SUPPLY REQUIREMENTS
UPPER WILLS CREEK AREA
SUBDIVISION NO. 5

FIGURE 20



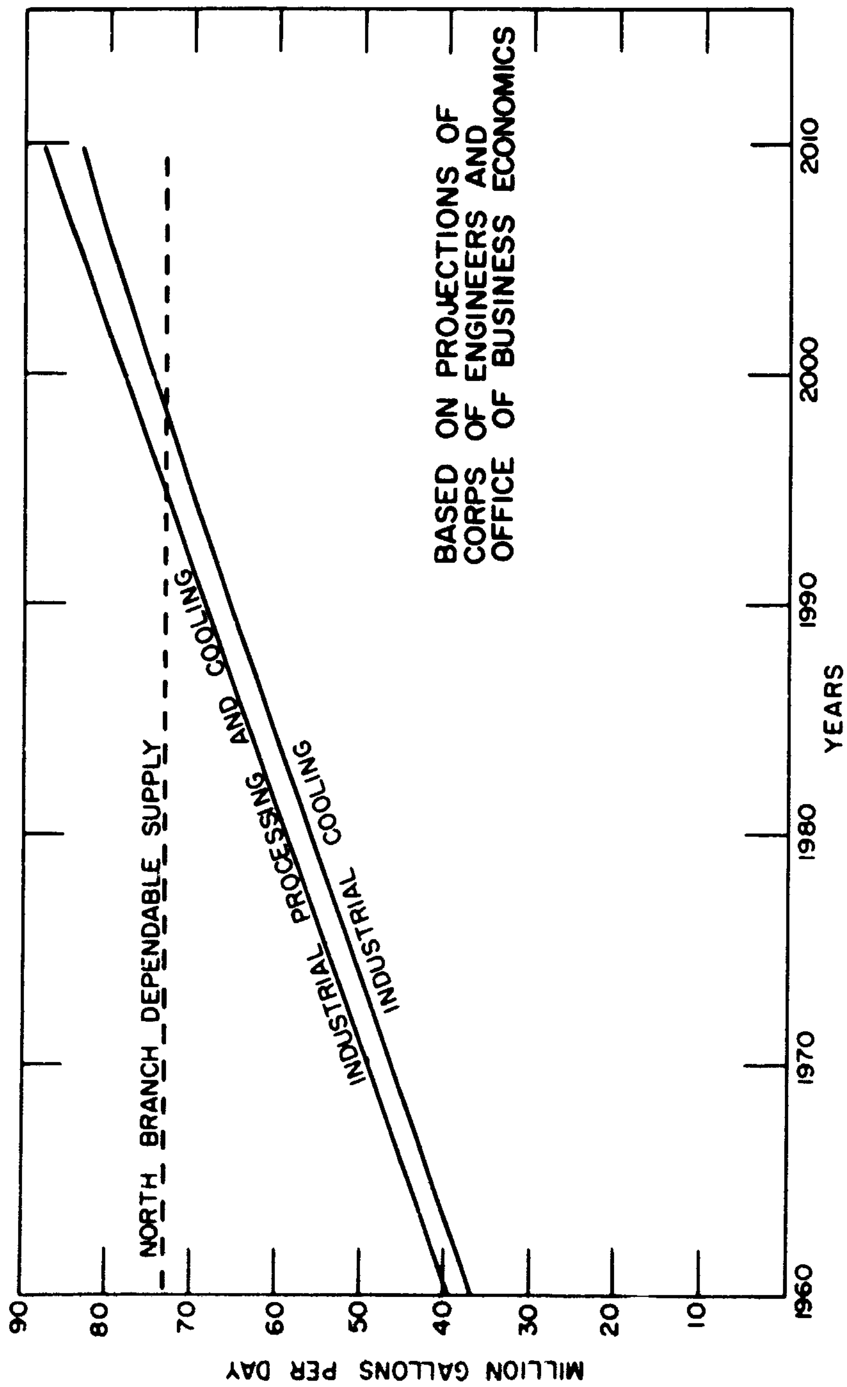
NORTH BRANCH POTOMAC RIVER
MUNICIPAL WATER SUPPLY REQUIREMENTS
LOWER PATTERSON CREEK AREA
SUBDIVISION NO. 6

FIGURE 21



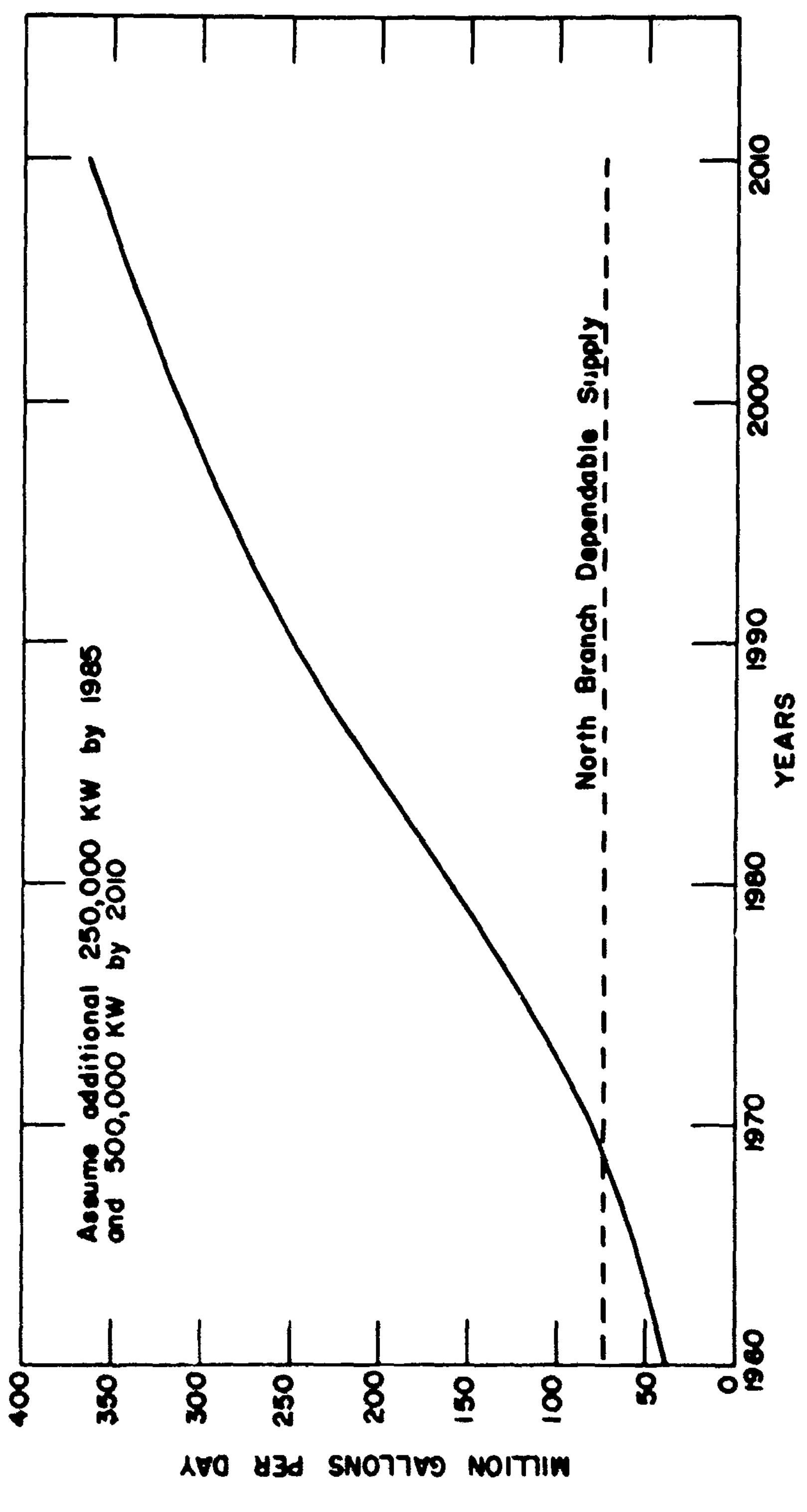
NORTH BRANCH POTOMAC RIVER
MUNICIPAL AND INDUSTRIAL WATER SUPPLY REQUIREMENTS
LUKE-KEYSER AREA
SUBDIVISION NO. 2

FIGURE 22



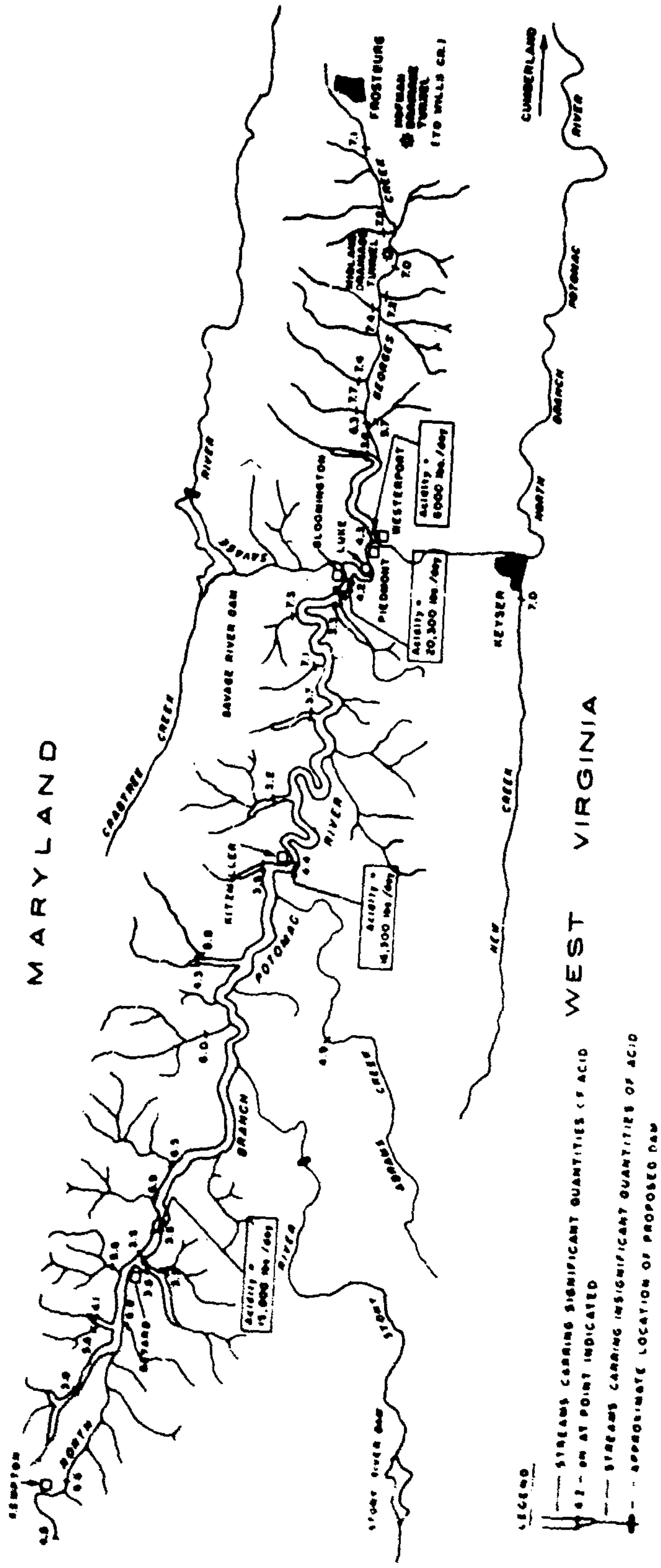
NORTH BRANCH POTOMAC RIVER
INDUSTRIAL WATER SUPPLY REQUIREMENTS
CUMBERLAND AREA
SUBDIVISION NO. 3

FIGURE 23



NORTH BRANCH POTOMAC RIVER
STREAM-ELECTRIC WATER SUPPLY REQUIREMENTS
CUMBERLAND AREA
SUBDIVISION NO. 3

FIGURE 24



EXTENT OF POLLUTION FROM ACID MINE DRAINAGE IN THE BASIN OF THE NORTH BRANCH POTOMAC RIVER

FIGURE 25

At the time of the 1956 field study, the Fairfax Coal Washery near Bayard discharged large quantities of coal fines to the North Branch. The washery fines were observed in the river many miles downstream from the plant, but due to deposition on the stream bottom, were barely visible at Luke. The large amounts of settled solids present in the stream waters receiving washery wastes tend to inhibit or suffocate aquatic bottom life in the affected reach.

The West Virginia Pulp and Paper Company at Luke, Maryland, recently made provision for doubling pulp and paper production (400 to 800 tons per day). An activated sludge plant for treatment of sulfate pulp and paper wastes has recently been completed by the Upper Potomac Commission. According to Company officials, the treatment plant in combination with increased efficiencies within the paper mill results in a waste load to the river of no greater than 16,000 pounds of 5-day, 20°C biochemical oxygen demand (BOD_5) and 34,000 pounds of suspended solids per day. During the stream survey of 1956, the plant was discharging 47,000 pounds BOD_5 and 106,000 pounds suspended solids per day.

Computations incorporating the reduced waste loads and minimum stream flows reveal that the condition of the North Branch between Luke and Cresaptown has been improved - from the standpoint of dissolved oxygen content - as a result of waste treatment at the West Virginia Pulp and Paper Company. However, since this form of waste treatment has little effect in reducing color, taste and odor producing materials, resin soaps, caustic substances, etc., the North Branch downstream from Luke remains unsuited for use as a source of raw water for municipal supply and certain industrial processing purposes (see Table 19).

The Celanese Corporation Plant, located on the North Branch between Cresaptown and Cumberland, discharges untreated wastes containing about 10,000 pounds of BOD_5 per day according to data obtained in 1956. This waste, in addition to residual pulp and paper waste from upstream, further degrades stream water quality.

Domestic sewage enters the North Branch from every community located along its banks. Sewage collected at Luke, Westernport, and Piedmont will be treated by the Upper Potomac River Commission treatment plant. Subsequent to the 1956 field survey, the City of Cumberland provided primary treatment facilities which accomplish partial treatment of municipal wastes. By this form of treatment, it is estimated that the waste load to the North Branch from Cumberland has been reduced from 8,200 to 5,400 pounds BOD_5 per day.

The condition of the North Branch throughout the entire Luke-Oldtown reach is estimated to be considerably improved over the extremely critical condition that existed prior to industrial waste treatment at Luke and municipal waste treatment at Cumberland.

Treated municipal wastes to be received in the Luke-Keyser reach of the North Branch by 1985 and 2010 would be expected to contain 550 pounds and 735 pounds BOD_5 per day, respectively. At Cumberland, the

treated municipal wastes expected to be received in the North Branch by 1985 and 2010 would contain 9,000 pounds (primary sewage treatment) and 3,400 pounds (secondary sewage treatment) BOD_5 per day, respectively. Treated pulp and paper wastes discharged to the North Branch in the vicinity of Luke by 1985 and 2010 would be expected to contain 32,000 pounds and 48,000 pounds BOD_5 per day, respectively. Treated industrial chemical wastes that would be received in the North Branch immediately upstream from Cumberland for all future years would be expected to contain no greater than 10,000 pounds of BOD_5 per day.

With the degree of waste treatment expected by 1985 and 2010 at municipalities upstream from Luke and along Georges Creek, Wills Creek, and Patterson Creek, it is assumed that the quality and condition of these streams would be protected.

TABLE 19

Typical Concentrations of Color, Tannin, and Lignin

1956 PHS Survey

Station No. and Location	Flow at Luke (cfs)	Color* (ppm)	Tannin and Lignin (as Tannin-ppm)
6 - Above Luke			
(Bloomington)	274	0	0.20
	260	1	0.20
	260	0	0.75
	345	2	0.30
	734	6	0.80
	472	8	0.35
	385	3	0.20
9 - Below Luke			
(Westernport)	274	18	5.5
	260	204	8.6
	260	99	8.5
	345	93	3.5
	734	32	1.7
	472	49	1.6
	385	63	2.7
	236	250	12.5
22 - Below Luke			
(Oldtown)	195	41	1.35
	228	61	1.85
	239	47	1.90
	734	53	1.50
	385	54	1.40

*PHS Drinking Water Standards - Color 20 ppm

STREAM QUALITY OBJECTIVES

Natural water quality is altered by man in as many or more ways as there are numbers of polluting substances. Materials of certain types and quantities when disposed of to stream water can unbalance the biological equilibrium of the stream, reduce recreation values, interfere with legitimate downstream uses and in some instances create serious nuisances and public health hazards, all of which become liabilities to the area affected.

Methods and facilities for treating wastes before discharge to streams, in many instances, have barely kept up with new production facilities and population growths because of the additional pollution created by new sources and increasing quantities of wastes from existing sources. The end result, in many areas, is very little if any improvement in the quality of receiving stream waters compared with conditions existing when improvement was initially required. Treatment plant effluents contain reduced organic waste concentrations and materials not removed by conventional treatment methods and because of increasing volumes may possess total loads greater than can be tolerated in the stream.

The characteristics of waste effluents change with refinements in treatment methods, sometimes for the betterment and other times for the detriment of receiving stream water. It is becoming more evident that highly treated wastes promote nutrient enrichments which stimulate algal nuisances in lakes, estuaries, and impoundments, where less highly treated wastes formerly had not promoted such nuisances. In such instances the respiration and decay of algal cells can have as great or greater detrimental effect than that produced directly by lesser treated wastes.

Increased stream flow, therefore, has particularly great value during extreme drought periods when concentrations of nutrients are highest and where waste treatment is not sufficient to protect the receiving stream. The value of such flows for benefit computation purposes would be equivalent to greater than present day conventional treatment costs or equivalent to the cost involved in attaining certain levels of tertiary treatment. It should be pointed out, however, that tertiary treatment as now known would not be the equivalent of low flow augmentation that would provide similar reduction in oxygen demanding substances. Since it is not known to what extent waste load reductions by future treatment methods will exceed present conventional treatment efficiencies, stream flow requirements for pollution abatement are determined as that flow which in combination with optimum treatment efficiencies presently possible, will result in an improved stream water quality. To obtain future industrial waste loads, a factor relating to projected water use is applied to existing treated waste loads.

The stream BOD loads from waste effluent sources, together with the effects of these loads on dissolved oxygen levels in the stream are usually used as a basis for determining minimum flow requirements. Whereas other pollutional parameters exist, these parameters offer a convenient means of determining benefits based on costs to obtain BOD reductions, with available treatment methods similar to assimilated reductions achieved with the augmented flow. In some instances, it may be necessary to base water quality objectives on waste substances not removed by conventional treatment. In this event, flow requirements may be based on dilution requirements to control concentrations of these substances. Benefits in this case may be equivalent to costs involved to develop the required stream flow.

Where several waste loads are received in a given stream reach, the BOD loads from each source are accumulated with proper allowances for assimilation between sources, to a point or points of maximum stream loading. The required flow given is that which in combination with the BOD load and stream assimilative capacity at the point of maximum load results in the 50 per cent saturation figure at the lowest point of the dissolved oxygen sag curve. Purification factors and dissolved oxygen deficits used to compute maximum allowable BOD loads for various stream reaches are based on stream sampling data.

The stream water quality objectives established for the North Branch by the Maryland Water Pollution Control Commission in September 1953 pertain mostly to the quality of wastes and waste effluents discharged; whereas, the proposed objectives adopted by the Interstate Commission on the Potomac River Basin in August 1946 pertain exclusively to quality of stream waters (see Exhibits A and B). In only one respect, that of minimum dissolved oxygen to be maintained in the stream, do the objectives of both agencies directly coincide. Maryland permits dissolved oxygen depletions to no greater than 50 per cent of saturation and the Interstate Commission requires no less than an average monthly minimum of 4.0 ppm (Class D water quality objective for general sanitation to prevent nuisance conditions). Both dissolved oxygen objectives are interpreted, therefore, as being essentially the same. Class C water quality (Interstate Commission classification) or that pertaining to raw water for municipal and industrial processing use involves impurities, some of which do not affect dissolved oxygen, but which are not and cannot be removed by any known practical treatment. Such materials may be classed as exotic or persistent types which often originate from various industrial processes and which impart discolorations and objectionable tastes and odors to the receiving stream waters.

Activated sludge treatment at Luke and primary sewage treatment at Cumberland appears (by computation) to have accomplished considerable improvements in minimum dissolved oxygen levels in the North Branch by providing substantial capacity for reducing the BOD_5 and suspended solids material contained in the raw waste. Treated pulp and paper wastes, however, contain considerable color and other

impurities which upon discharge to the low flow of the North Branch, produce a water quality unsuited for municipal and certain industrial processing purposes downstream.

Since the Class C water quality objectives cannot be met by presently known treatment techniques, the objectives of water quality management on the North Branch is to maintain Class D dissolved oxygen objectives and develop a means of minimizing concentrations of persistent materials and nutrients that would be carried great distances downstream and well into the main stem of the Potomac River.

EXHIBIT A

Maryland Water Pollution Control Commission Standards for Industrial Waste Discharge

No industrial wastes other than acid-mine drainage shall be placed or permitted to be placed or discharged or permitted to flow into any of the waters of the State in any manner by any person unless the industrial wastes after treatment or untreated shall meet with the nine industrial waste requirements established by the Water Pollution Control Commission before being discharged into any waters of the State. These nine industrial waste requirements are as follows:

1. Solids:

   A. Solids in the effluent - Must not exceed 1/32 inch particle size. Grinding, maceration or any other waste treatment or handling operation intended to reduce the size of the over-size solids in the effluent to less than 1/32 inch will not be permitted or approved.

   B. Total suspended solids - Must not exceed 1500 ppm.

   C. Dissolved solids - Must not exceed 1500 ppm.

   D. Total Solids - Must not exceed 1900 ppm.

2. Turbidity - Must transmit 10% of light through 12 inches of sample in a 3 inch column or not to exceed 300 ppm., as determined by the Jackson Candle turbidimeter.

3. Biochemical Oxygen Demand:

   A. The biochemical Oxygen Demand - The 5-day-20°C. Biochemical Oxygen Demand in the effluent must not exceed 100 ppm.

   or

   B. The Dissolved Oxygen in the waste receiving waters must not be depleted beyond 50% of normal saturation.

4. Toxicity or toxic compounds - Eliminate, or reduce to limits of tolerance, substances toxic to humans, livestock, fish, aquatic and wildlife.

5. Color - Color intensity regardless of light frequency must not exceed 400 ppm on the chloroplatinate scale.

6. pH - Must not range below 5.5 or above 8.5.

7. Temperature - Must be below 100 degrees F in the stream within 50 feet from waste outlet.

8. Oils and grease in the effluent must not exceed 30 ppm.

9. Taste and odor - Effluent must not exceed threshold odor number of 1000. Mixture of the waste and receiving waters shall have a threshold odor number not in excess of 80.

All analyses to be conducted in accordance with the American Public Health Association Standard Methods.

These nine industrial waste requirements are generally applicable values but are not absolutely fixed values. They can be made more stringent if a survey of the waste-receiving waters indicates they are still polluted or are continuing to be degraded, or in any instances where the Water Pollution Control Commission after due study and deliberation deems that more stringent requirements are necessary. They can be made more liberal only by formal action of the Commission on the basis of satisfactory evidence and proof that waste-receiving waters are sufficient in quantity and quality to not be affected adversely by a particular industrial waste effluent having values in excess of those stated above.

Any industrial wastes, after treatment or untreated, which do not meet with the above requirements shall be deemed and considered in violation of this regulation based on Laws of Maryland, Chapter 697 of the Acts of the General Assembly of the State of Maryland of 1947, and shall be subject to penalties imposed thereby. Each day upon which a violation occurs under this regulation shall be deemed a separate and additional violation.

This revised regulation approved December 12, 1949 supersedes the previous Regulation IV which was effective August 1, 1948.

Revised and approved by the Water Pollution Control Commission, September 29, 1953.

STATE OF MARYLAND
WATER POLLUTION CONTROL COMMISSION

L. B. Phillips, Jr., Chairman
Paul W. McKee, Director

EXHIBIT "B"

Interstate Commission on the Potomac River Basin

Minimum Water Quality Criteria for Streams
in the Potomac River Basin

Approved 8 August 1946

	CLASS A Drinking Water (No treatment except cl.)	CLASS B Bathing, Fish Life	CLASS C Domestic Water Supplies (Before complete treatment) Industrial Process Water	CLASS D General Sanitary Condition - to prevent nuisance
Coliform Bacteria	0 - 50	Mo. av. 50 - 500 Max. not over 1,000	Mo. av. 500 - 5,000	----------
Color, ppm	0 - 10	20 (desirable)	Amt. of color and turbidity allowed which can be removed by standard equipment and practices	----------
Turbidity, ppm	0 - 10	40 (desirable)	----------	----------
pH	6.0 - 8.0	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
5-Day BOD, ppm	----------			
Monthly av., ppm	----------	1.5	2.0	3.0
Max. observation, ppm	----------	3.0	4.0	5.0
Dissolved Oxygen, ppm				
Monthly av., ppm	7.5	6.5	6.5	4.0 Min. daily ave. 3.0
Min. observation, ppm	6.5	5.0	5.0	Absolute min. 2.0
Other Conditions	No toxic substances, oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste - or odor-producing substances.	Same as A	Same as A	No toxic substances, oils, tars, or free acid at any time. No floating solids or debris except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

NOTE: These criteria are to be used only in conjunction with a sanitary survey as a guide in determining the minimum water quality for the various classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.

The Maryland State Department of Health can require reductions of water pollution wherever a public health menace exists. No overall criteria for pollutional limits are established, and each case is considered separately.

METHODS TO ACCOMPLISH OBJECTIVES

WATER QUALITY

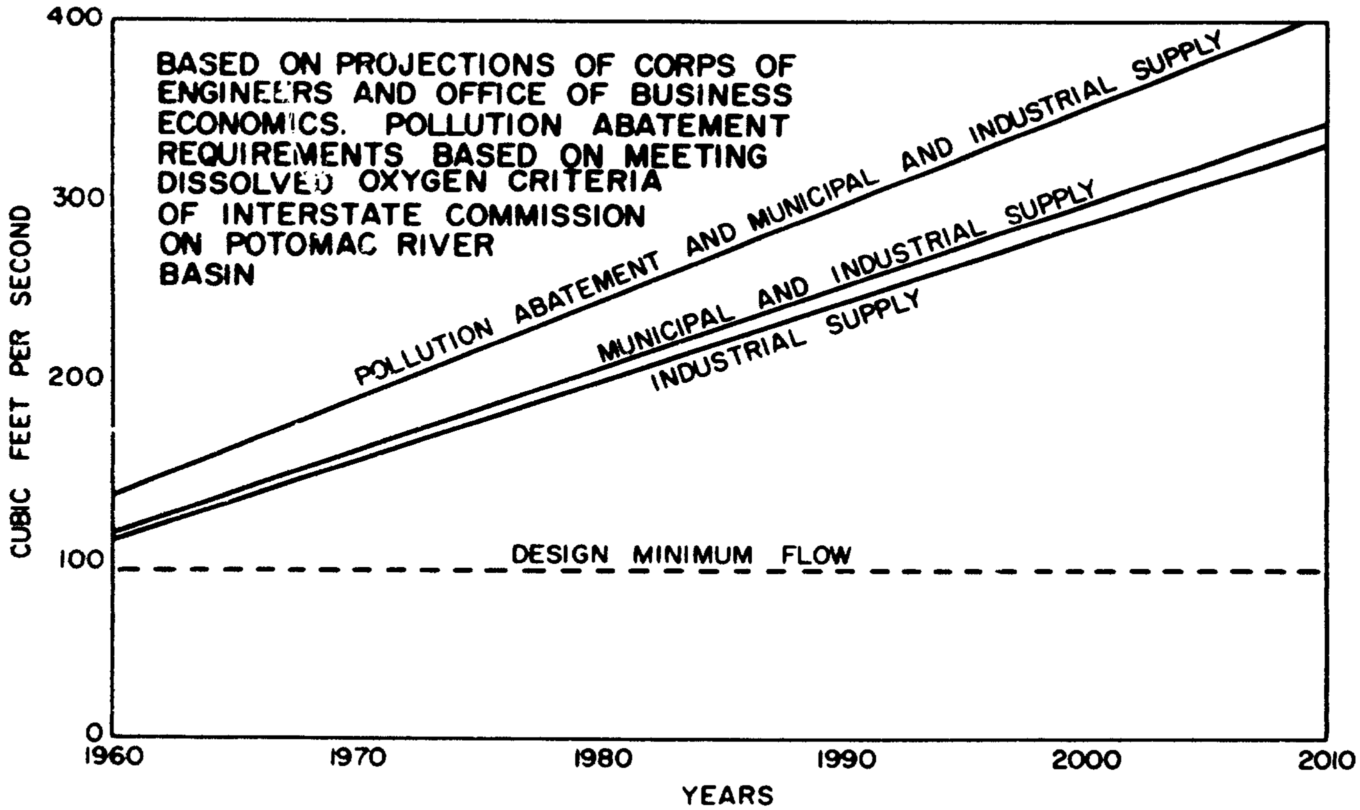
In order to maintain stream water quality objectives and to prevent serious waste effects from extending far downstream into the main stem of the Potomac River, future industrial expansion and population growth along the North Branch will necessitate the following: Provisions for increased treatment capacity and efficiency at all waste sources; vigilance by industry to expand in-plant recovery systems in proportion to production increases, and greater waste assimilative and dilution capacity in the form of increased minimum continuous stream flows.

It is believed that dissolved oxygen levels in the North Branch have been improved as a result of activated sludge treatment at Luke. Computations show, however, that despite this high degree of waste treatment, the discharged effluent contains residual BOD_5 in excess of loadings associated with Maryland and Interstate Commission dissolved oxygen objectives.

The highest practical degree of waste treatment, i.e., activated sludge treatment in combination with additional assimilative capacity provided by increased stream flows, would be necessary to meet dissolved oxygen objectives in the North Branch downstream from Luke.

In addition to the need for increased stream flows to control future dissolved oxygen depletions, it would be necessary to provide a means for minimizing concentrations of color producing and persistent chemical substances. However, since no conventional treatment method for reducing these substances exists, the only possible method available to accomplish this control is by dilution with increased stream flow. Since dilution flows in the waste-receiving stream are an indispensible part of waste treatment in the North Branch, it is imperative that, for every unit of water taken from the stream and returned as process waste, an additional quantity be allowed to remain in the stream to receive and further treat and dilute this waste. Figure 26 shows the total flow and proportions of flow that would be required for water supply and for waste treatment in the Luke area.

To meet water quality objectives in the Cresaptown area, treatment of industrial wastes would be required. With an increase to 2.5 times present industrial production by the year 2010, treatment to remove about 60 per cent of the BOD_5 would provide the necessary control.



NORTH BRANCH POTOMAC RIVER
FLOW REQUIREMENTS FOR WATER SUPPLY
AND POLLUTION ABATEMENT
LUKE AREA

FIGURE 26

At Cumberland, primary treatment of wastes would only be sufficient to about the year 1962, after which time secondary treatment of the ultimate expected population loads would be sufficient to maintain dissolved oxygen objectives in the downstream reach.

WATER SUPPLY - QUANTITY

Factors considered in planning for future water supply involve purposes of use, quantities and quality requirements, available sources, and equitable costs involved in satisfying the particular requirements.

The North Branch waters although possessing acid characteristics are of suitable quality (process water treated for acid reduction) for pulp and paper production. No other source with sufficient dependable quantity exists in this area.

Since the entire dependable supply of the North Branch at Luke is used for pulp and paper production at the present time, upstream single purpose storage will be required to meet anticipated production and domestic requirements in this area in the future (see Figure 27).

As self-supplied chemical and commodity producing industries in the Cumberland area are able to tolerate the degraded quality of North Branch waters downstream from pulp and paper waste discharges, no change in source, with respect to quality, is expected for these uses in the future. Since water quantity demands for these purposes are expected to exceed the present dependable supply of the North Branch in the future (see Figure 28), development of a new source to provide at least similar quality and the required quantity would be necessary in the absence of any additional upstream development by other.

Water for municipal purposes has first priority when planning is made to meet future quantity and quality requirements. Development of another source to supplement the Evitts Creek supply now serving the Cumberland area is anticipated for the future (see Figure 29). A source other than the North Branch which would provide suitable quantity and quality would be required.

Where cooling water requirements exceed the volume of water available, the user may elect to increase the supply by augmentation methods, or install cooling towers and recirculate a major portion of available water. By resorting to the use of cooling towers, the operation objective can be achieved, although at the expense "of poor efficiency and resulting higher costs."[1] No attempt is made in this report to evaluate differences in internal efficiencies and capital costs for thermal power units operated solely on river water, and those operated with cooling towers. Only costs to achieve cooling are considered.

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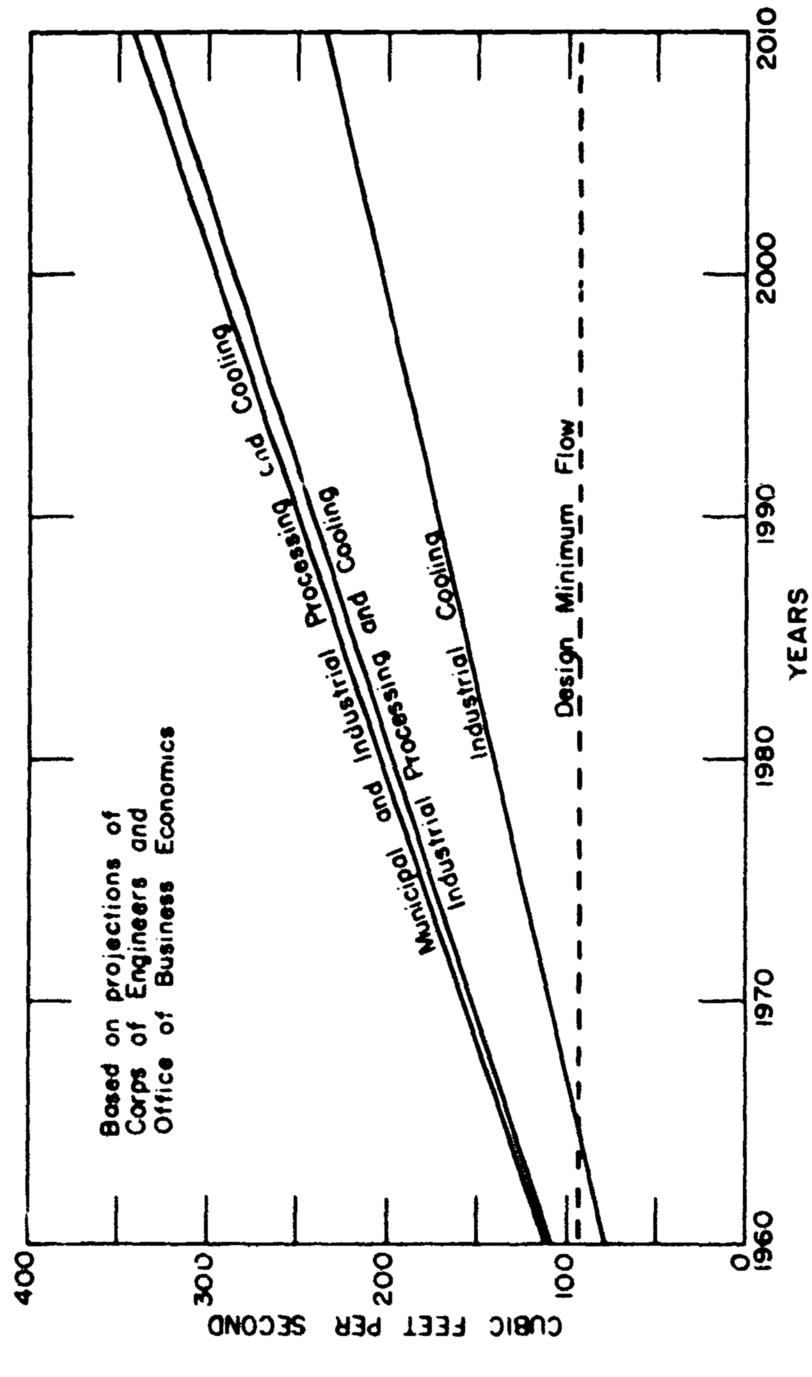
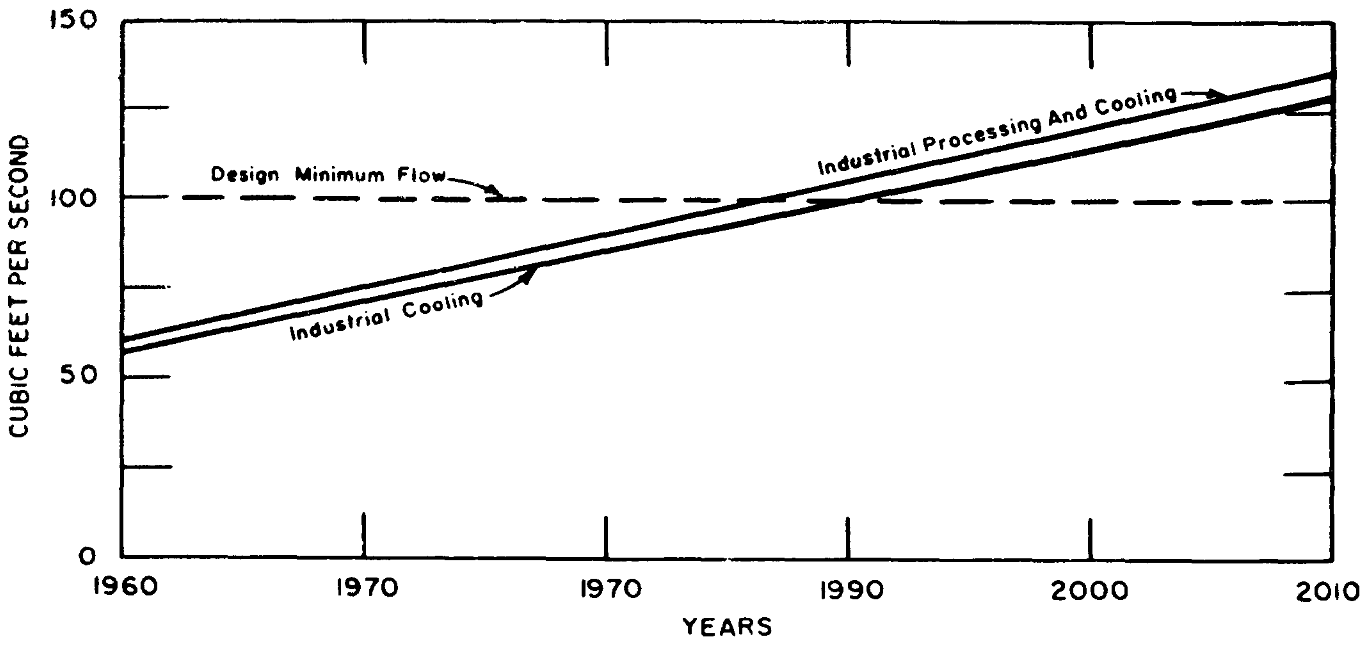
1 - Detroit Edison Company, June 1959



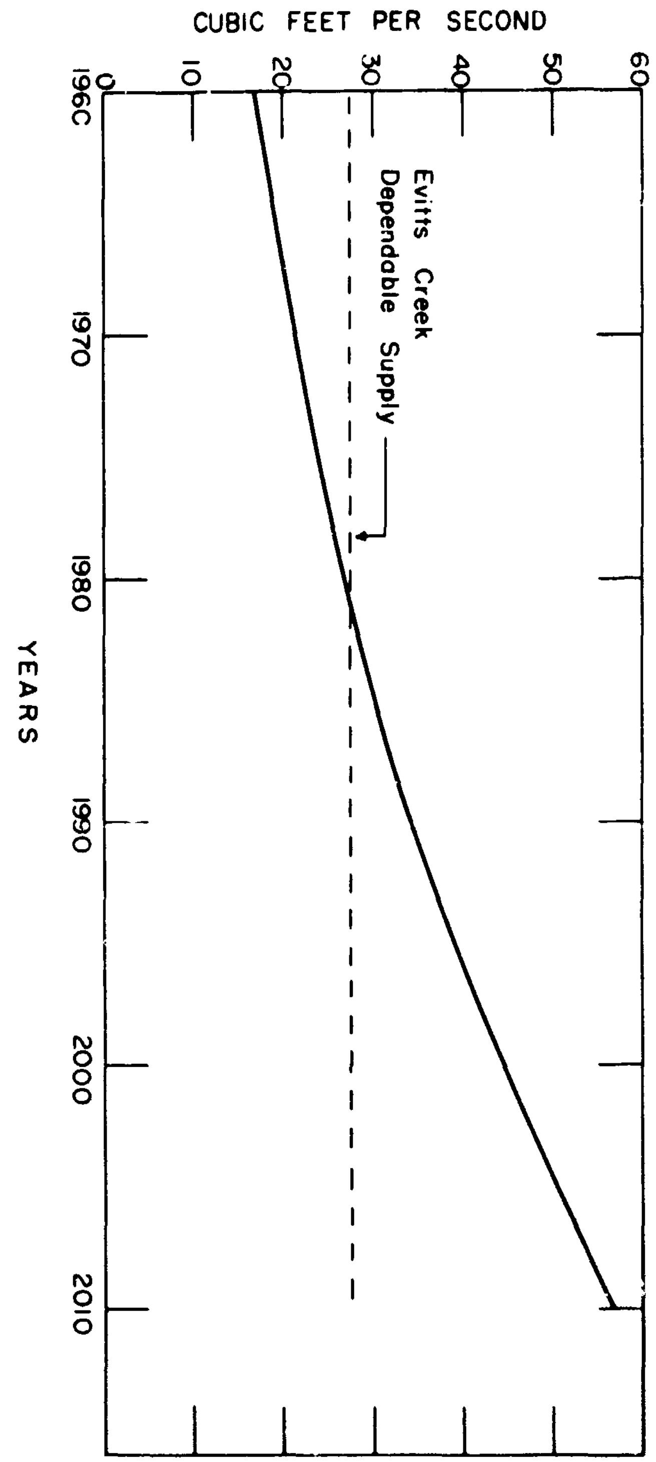
NORTH BRANCH POTOMAC RIVER
FLOW REQUIREMENTS FOR WATER SUPPLY
LUKE AREA

FIGURE 27



NORTH BRANCH POTOMAC RIVER
FLOW REQUIREMENTS FOR WATER SUPPLY
CRESAPTOWN AREA

FIGURE 28



NORTH BRANCH POTOMAC RIVER
FLOW REQUIREMENTS FOR MUNICIPAL WATER SUPPLY
CUMBERLAND AREA

FIGURE 29

In the process of evaporation, heat is taken away from heated surfaces by the vapor produced. This heat is called "latent heat of vaporization." When in contact with the atmosphere, this heat is absorbed in the air, resulting in condensed vapor temperatures lower than that of the atmospheric temperature. For example, when one pound of water is evaporated, approximately 1,000 BTU are removed in the form of latent heat.[1] Air absorption of this heat makes reductions in water temperature (less than atmospheric temperature) possible by cooling towers. This temperature is referred to as "dry-bulb temperature."

Evaporation and cooling tower efficiencies are limited by the relative humidity of the atmosphere. Since relative humidity is a measure of the amount of moisture that may be present in the air in relation to the total capacity of air to hold this moisture, it follows that evaporation at relative humidity of 100 per cent could not take place. The temperature-humidity relationship is referred to as "wet-bulb temperature."

Measurements of cooling tower efficiency are based on the ability of cooling towers to bring water temperature to the "wet-bulb temperature" of the surrounding air. At lower "wet-bulb temperatures" - which indicate either cool air, low humidity, or a combination of both - more efficient cooling can be achieved. It is important to note that cooling towers cannot reduce water temperatures to below the "wet-bulb temperature" of the incoming air.

In summary, cooling tower operation by virtue of utilizing evaporation mechanisms to achieve cooling, results in vapor losses to the atmosphere of about one per cent of that passed through the towers for each 10°F. of cooling. However, in being absorbed in the atmosphere, this amount of evaporated water removes a large quantity of heat from the water that is recovered.

Other water losses that occur in cooling tower operations are from drift (water in droplet form) and bleed-off. Evaporation and drift are considered as consumptive uses, whereas bleed-off is not since it is returned to the river.

Make-up water consists of water lost in evaporation, drift, and bleed-off. In relating the consumptive use portion of make-up water to value equivalent with augmented river flow, an estimation of the difference between consumptive use by cooling tower and river water operation should be made.

The value of augmented river flow, based on cooling tower operation to accomplish the required cooling capacity, should include capital and operation costs for cooling towers and costs to replace the amount of make-up water which represents the difference between cooling tower and river operation.

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1 - British Thermal Unit - heat energy required to raise the temperature of one pound of water one degree Fahrenheit in the range of 32° to 212°F.

PROPOSED WATER STORAGE AND EFFECTS

Three possible reservoirs in the North Branch watershed above Luke are considered from which low flow increases could be obtained, in addition to that from the existing reservoir on the Savage River (see Figure 1). Flow regulation could be accomplished from a reservoir on Stony River, located downstream of U. S. Route 50 crossing, and a new reservoir on the Savage River above the present impoundment. A third reservoir is proposed for the North Branch above Bloomington. The combined low flow that could be developed, including regulation from the existing Savage Reservoir is estimated to be approximately 380 cfs at Luke.

The stream waters relative to the proposed Savage River Reservoir are of excellent quality and contain no appreciable acid-mine drainage or iron and manganese. Waters at the proposed Stony River Reservoir contain no measurable mineral acidity, but contain iron and manganese of such magnitude during low flows that facilities would be required for reduction of these elements, in order for the waters to be used as a water supply and to comply with Public Health Service drinking water standards (combined iron and manganese - maximum 0.3 ppm). Waters relative to the proposed North Branch reservoir above Luke are extremely acid during low flows (mean annual - pH 4.5) and therefore do not meet objectives for domestic raw water quality (pH 6.0 - 8.5).

The Savage and Stony River impoundments would provide recreational attractions to the region, including boating, fishing, and swimming. Because of acid waters, the North Branch impoundment would not be expected to produce certain fish. When impounded, the acid waters of the North Branch would be expected to damage submerged concrete and metal structures unless adequate protective measures are applied. By augmenting the low flow of the North Branch with acid-free waters from Stony and Savage River Reservoirs, a decided reduction in acidity of stream water would be obtained for use at Luke. The North Branch Reservoir, by virtue of the catchment of waters during rainy seasons when acid-mine drainage is more dilute, would provide waters containing less acidity at Luke than exist under present free-flowing low flow conditions.

Waters released from low level storage pools immediately upstream from Luke would have less seasonal temperature variation than that of the natural stream, and where used for industrial cooling purposes would contribute to improved condensing and cooling efficiencies.

The maximum low flow increase that could be developed from the three proposed reservoirs, together with the existing low flow, could not provide sufficient dilution of colored wastes received in the North Branch at Luke to allow use of these waters for municipal supply purposes at Cumberland.

Low flow increases of the magnitude proposed for the three reservoirs would furnish adequate industrial water and would provide waste dilution and treatment capacity required in the North Branch downstream from existing and expected sources of wastes.

BENEFITS

Water Quality

Waters stored in the Upper North Branch region with provisions for controlled low flow increases downstream by use of multi-level outlets would possess quality characteristics and waste treatment capacity of significant benefit to downstream users.

Compared with the wide fluctuations in temperature and high acidity presently in existence in the North Branch, these waters by being stored would have a lower summer time temperature and would be reduced in acidity. When used for water supply, i.e., municipal, industrial processing and industrial cooling, as is the case in the Luke area, waters released from storage would provide benefits in terms of savings in treatment costs for acid reduction, saving in cooling water pumpage, and increased cooling efficiencies in terms of process water and thermal power production. In addition, waters of reduced acidity in storage and in the stream would provide more suitable environments for propagation of fish and other aquatic life and would accomplish control of pollution from acid-mine drainage, heretofore not successfully accomplished by other means. Since the only known method for reducing acidity is by use of neutralizing chemicals, the value and, therefore, the benefit assignable to stored water for abating the pollutional characteristics of acid-mine drainage is equivalent to the cost of chemicals required to accomplish a similar reduction. This is a conservative figure in that there are no facilities or manpower considered which are always found in a conventional neutralizing plant.

No known practical conventional waste treatment method, by itself, exists which will provide a form of waste treatment comparable to that obtainable with conventional treatment supplemented by increased stream flow for control of dissolved oxygen, color, and persistent waste substances. Therefore, the benefit assignable to the flow increase required to treat industrial waste effluents in the Luke area in a manner consistent with downstream water quality objectives is equivalent to the cost of providing the required dilution flows needed to supplement conventional treatment.

Acid Reduction

Benefits from acid reduction differ for each of the proposed reservoirs, i.e., the alkalinity of waters in the Stony and Savage Rivers differ, and tributary in-flow to a North Branch Reservoir would produce even more diverse acidic characteristics. For consistency in assigning benefits to various reservoirs separately or

in combination, benefits are given for various stream flows in the Luke area (includes existing 93 cfs). Neutralization of acid water by highly alkaline wastes at Luke would eliminate any further benefit to acid reduction downstream.

Benefits to water supply and pollution abatement by reduced acidity for the proposed reservoirs are given in Figures 30 and 31. The water supply and pollution abatement benefits for acid reduction are additive. For reservoir combination, the following methods of computation apply: (1) Stony and Savage Reservoirs - benefits are additive in proportion to flows from each; (2) Savage and North Branch Reservoirs - benefits are additive in proportion to flows from each; (3) Stony and North Branch Reservoirs - benefits are equivalent to that from the North Branch Reservoir alone; (4) Stony, Savage, and North Branch Reservoirs - benefits are equal to the sum of proportionate flows from the Savage and North Branch Reservoirs. All acidity reduction benefits are based on 1957 chemical costs.

Temperature Reduction

Benefits from temperature reduction in the Luke area would apply only to the Savage and North Branch Reservoirs, since the distance through which flows from the Stony Reservoir pass would be expected to produce temperatures in equilibrium with those of the atmosphere. By the same token, waters released from Savage and North Branch Reservoirs would not be expected to provide temperature reduction benefits in the Cresaptown or Cumberland areas.

Stream temperature data collected before and after installation of the existing Savage Reservoir reveal the magnitude of temperature reduction that may be expected from additional storage in the region. For example, releases ranging from 15 to 45 cfs from the proposed Savage Reservoir would be expected to result in reduced temperatures at Luke of 1.8 to 5.3°F. from the established present maximum of 66.9°F. Controlled releases of water from the North Branch Reservoir would be expected to possess temperatures equal to the average annual air temperature, or 53.2°F. which is a reduction of 13.7°F. at Luke. On an annual basis, the temperature reduction frequencies for the Savage River Reservoir for flows between 15 and 45 cfs are 281 to 789 degree-days, and for the North Branch Reservoir 1,373 degree-days at any flow. Savings in pumping costs ($0.20 per million gallons per degree Fahrenheit)[1] yield annual quality benefits for water used in the Luke area for cooling shown in Figure 32. The cooling water requirements to which these values apply are shown in Figure 36. In addition considerable benefits accrue from increased plant efficiency. However, their measurement was not possible at this time.

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1 - Allegany River Basin industries - 1957

NORTH BRANCH POTOMAC RIVER
ANNUAL ACID REDUCTION BENEFITS
FOR POLLUTION ABATEMENT

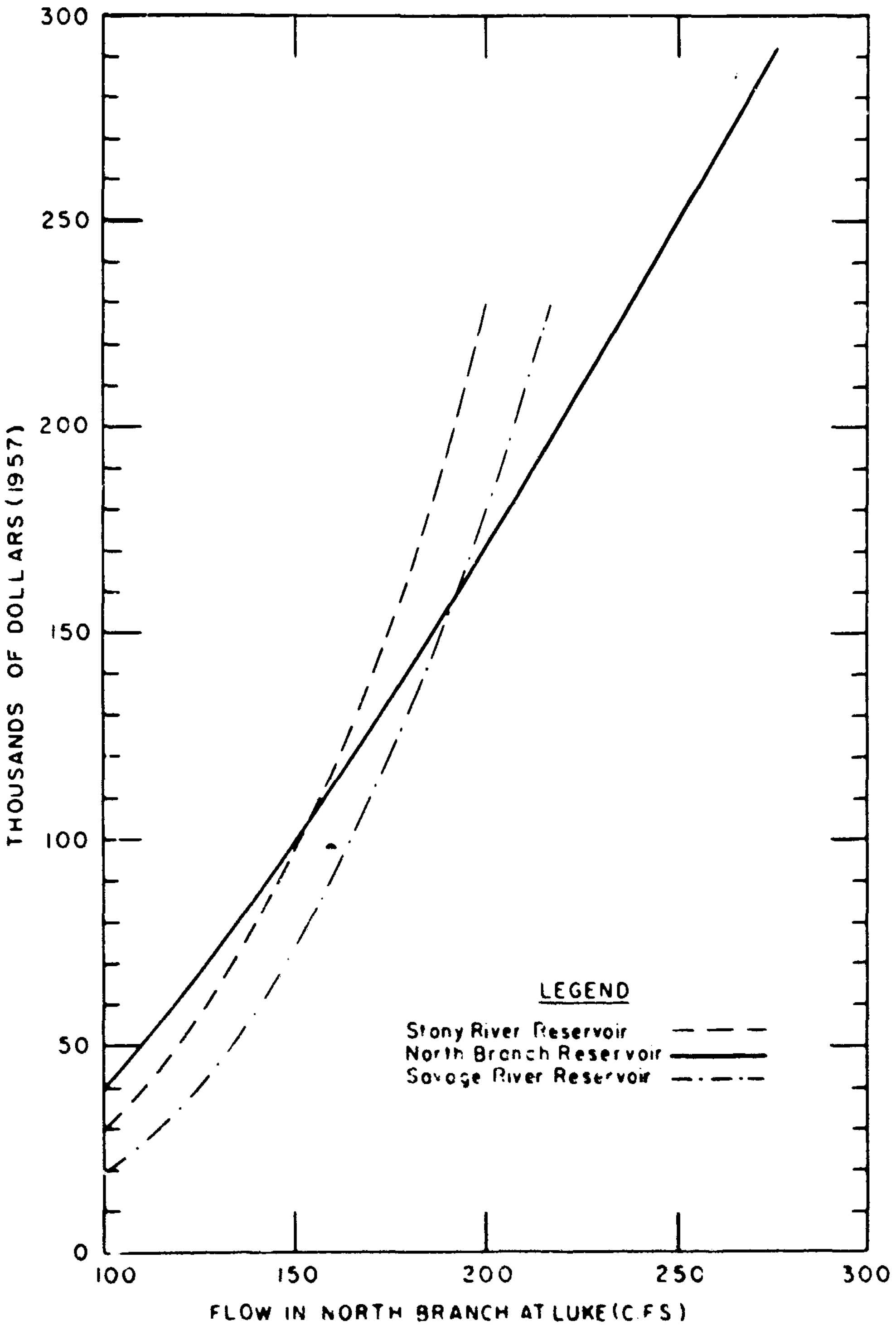

FIGURE 30

NORTH BRANCH POTOMAC RIVER
ANNUAL ACID REDUCTION BENEFITS
FOR WATER SUPPLY

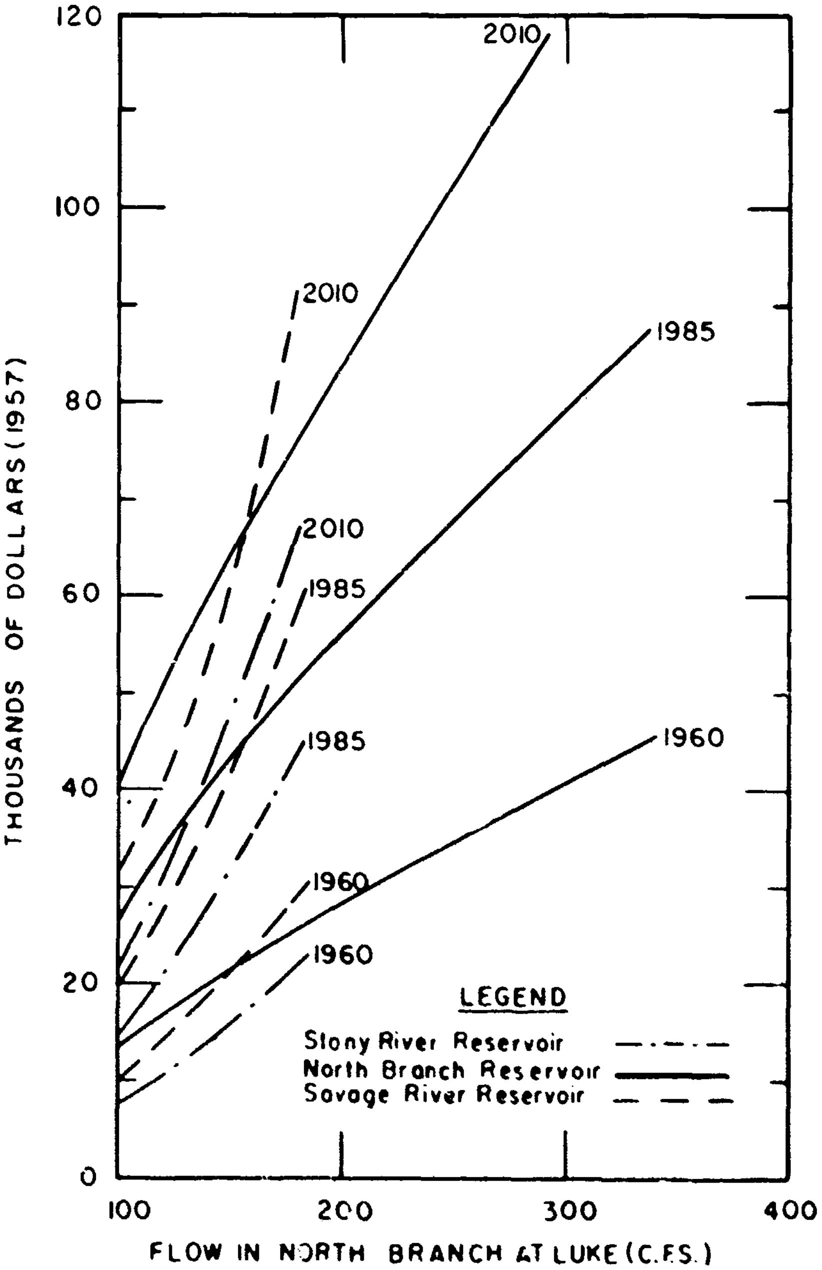

FIGURE 31

NORTH BRANCH POTOMAC RIVER
ANNUAL TEMPERATURE REDUCTION BENEFITS
PROPOSED RESERVOIRS SEPARATELY
1960 – 2010

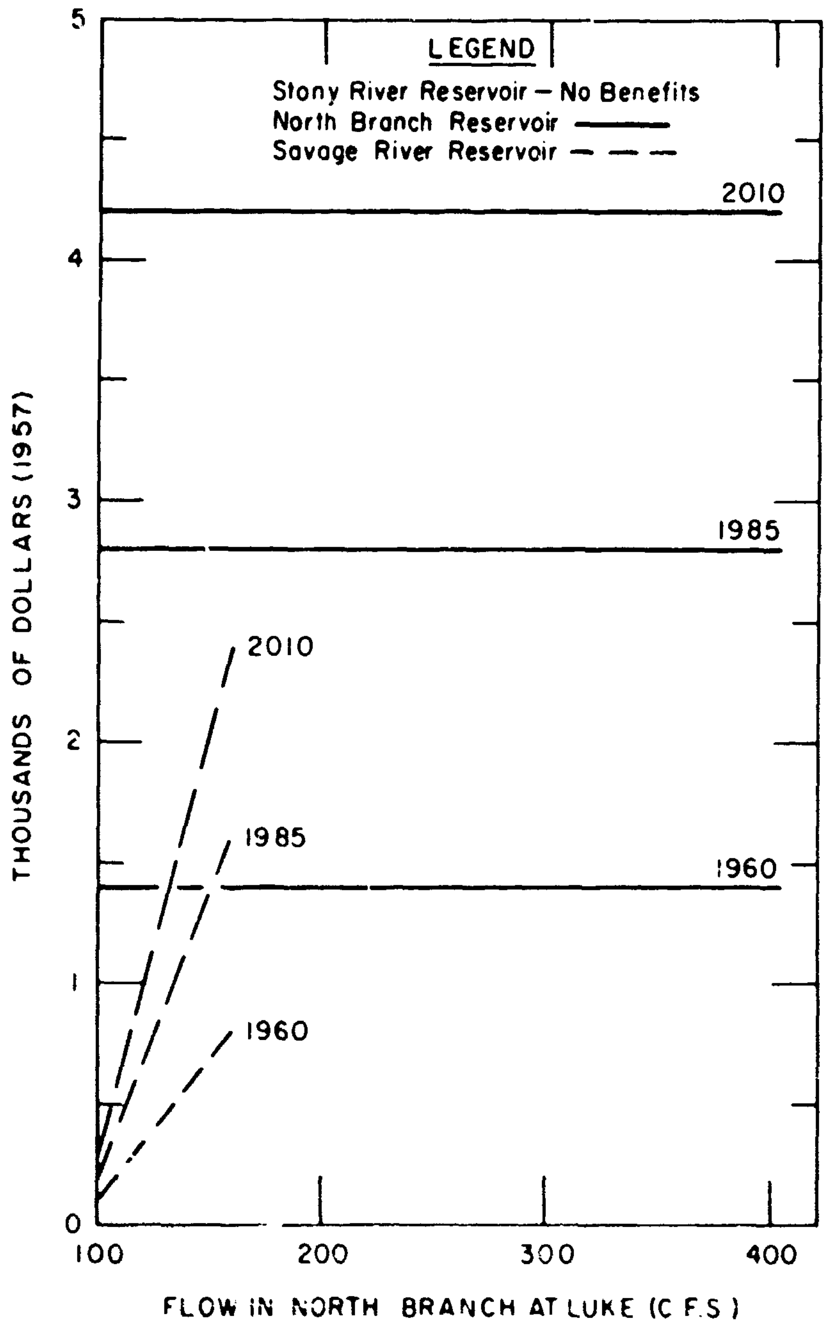

FIGURE 32

Waste Treatment

Benefits assignable to flow increases for waste treatment apply only to wastes received in the North Branch from the Luke area. Flow increases from any storage project would possess equal value in terms of annual benefits.

Dissolved Oxygen

Benefits assignable to increased flow for control of dissolved oxygen are equivalent to estimated costs involved in removing a portion of the residual BOD_5 contained in effluents from activated sludge treatment of pulp and paper wastes. The cost of such treatment is based on costs to provide theoretical multiple-treatment units based on investment and operation and maintenance costs involved in the existing plant. Treatment plant design is based on that required to maintain no greater than 22 ppm BOD_5 in the stream for control of dissolved oxygen at a minimum of 4.0 ppm. Benefits assignable to low flow augmentation for this purpose are shown in Figure 33. Control of dissolved oxygen, however, accomplishes only a part of the established water quality objective.

Biochemical Oxygen Demand

Benefits based on treatment costs to achieve BOD_5 concentrations in the stream similar to those accomplished by flow increases are shown in Figure 34. Costs for treatment are computed on the same basis as those for control of dissolved oxygen, i.e., theoretical multi-unit facilities. Benefits are limited in this case since the BOD objective (Class D - 3.0 ppm BOD_5) cannot be achieved with the maximum estimated development of water storage in the Upper North Branch region. To achieve the Interstate Commission objective for BOD_5 would require a total of about 1,000 cfs in the Luke area, or treatment to remove about 97 per cent of the BOD_5.

Color and Persistent Chemical Wastes

Conventional or theoretical multi-unit treatment facilities would not remove color and various other dissolved impurities from the pulp and paper wastes. Without sufficient increases in dilution flows to supplement activated sludge treatment for control of future increases in color and persistent chemicals, the objective for protecting downstream waters would not be met. Therefore, the benefits assignable to increased flows for control of concentrations of persistent materials and dissolved oxygen are equivalent to the most economical single purpose reservoir system that could be developed. The least expensive plan that could be developed would cost \$10,600 per cfs per year delivered to the Luke area[1]. Figure 35 shows the

1 - Washington District, Corps of Engineers in consultation with the Public Health Service. Assumes amortization over a 50-year period at 4 per cent.

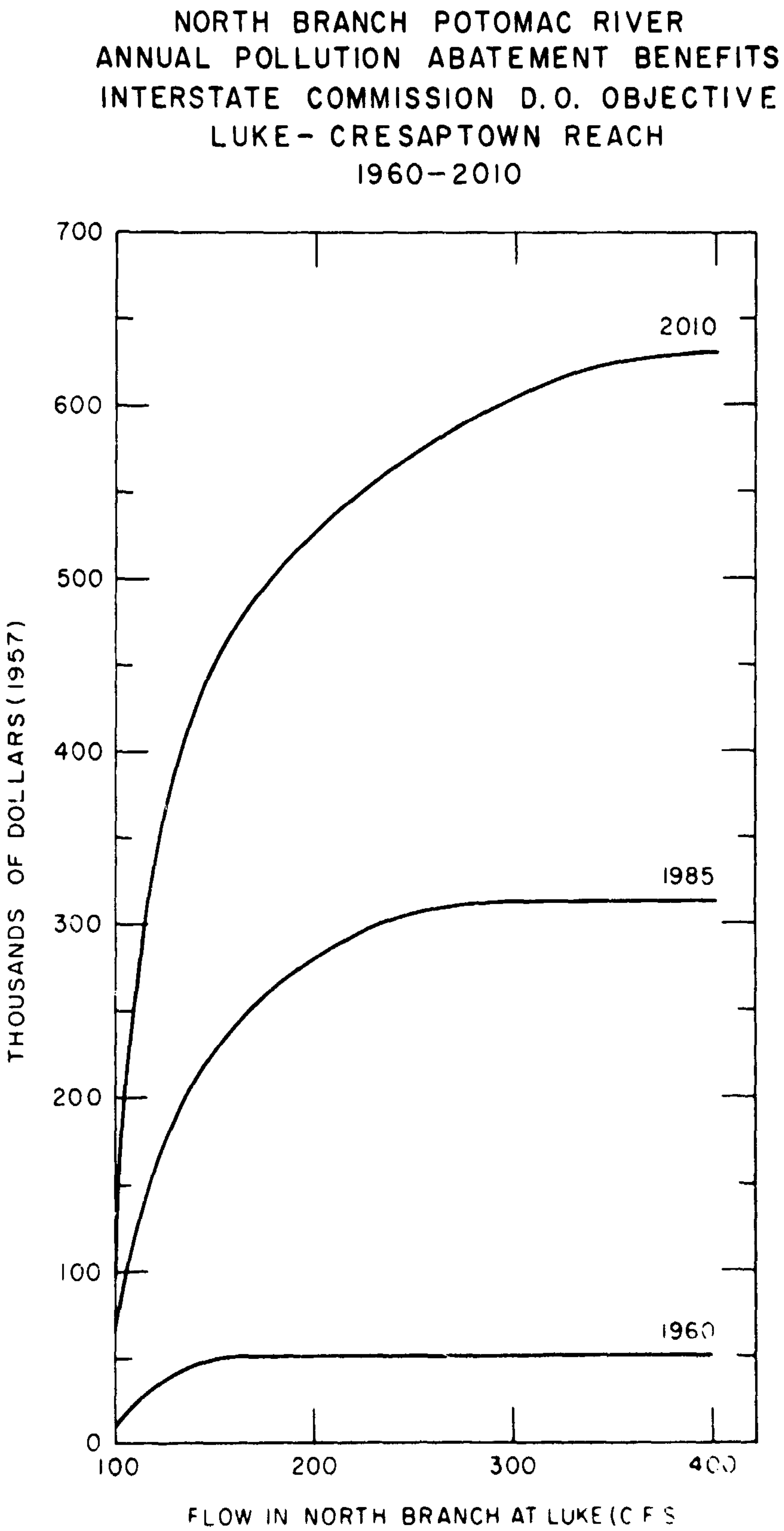
NORTH BRANCH POTOMAC RIVER
ANNUAL POLLUTION ABATEMENT BENEFITS
INTERSTATE COMMISSION D.O. OBJECTIVE
LUKE- CRESAPTOWN REACH
1960-2010
THOUSANDS OF DOLLARS (1957)
700
600
500
400
300
200
100
0
2010
1985
1960
100
200
300
400
FLOW IN NORTH BRANCH AT LUKE (C F S

FIGURE 33

NORTH BRANCH POTOMAC RIVER
ANNUAL POLLUTION ABATEMENT BENEFITS
INTERSTATE COMMISSION BOD_5 OBJECTIVE
LUKE – CRESAPTOWN REACH
1960 – 2010

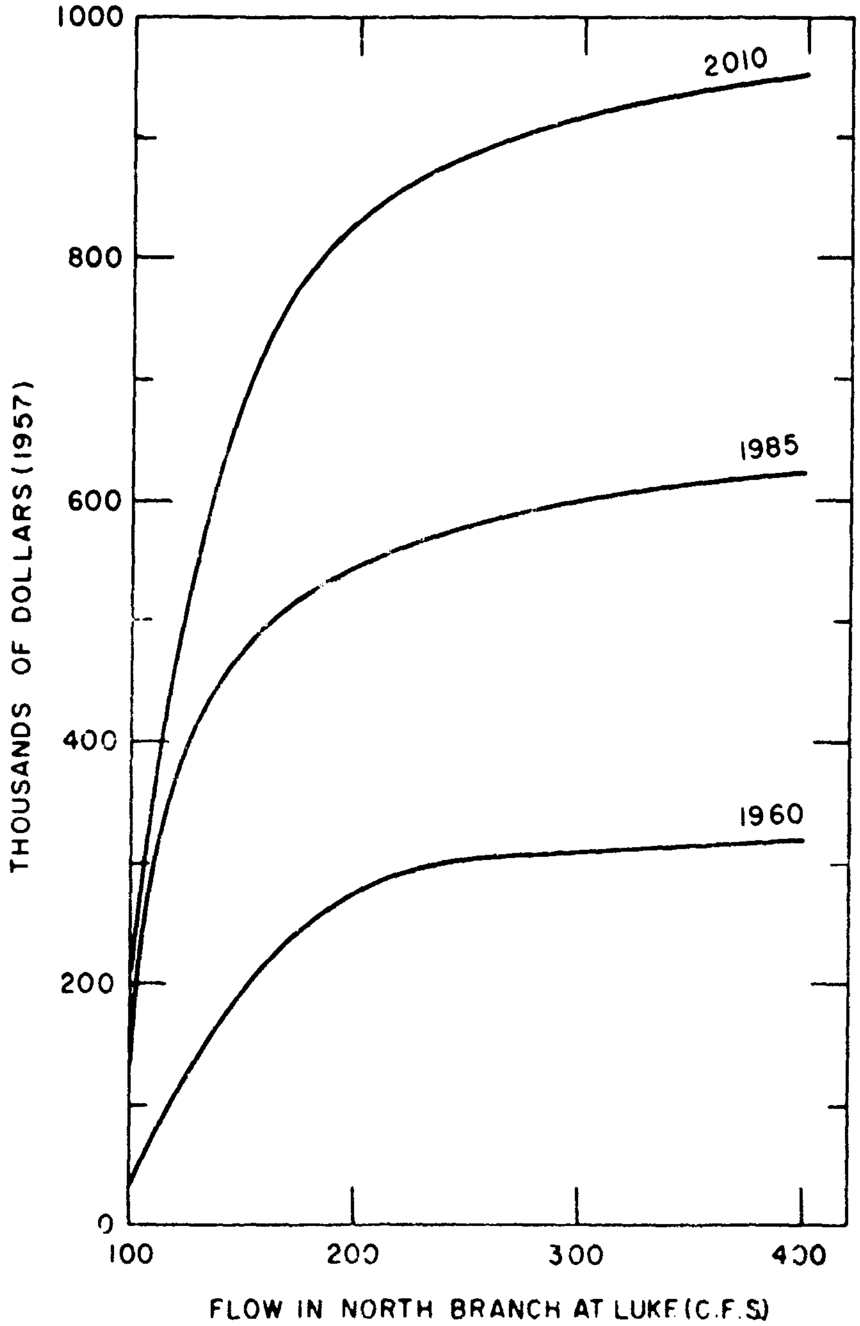

FIGURE 34

annual benefits that would apply for three typical time periods. Flow requirements to which these values apply are shown on Figure 36. It is noted that cooling water at Luke is included in the flow requirements for pollution abatement. The value of this water for pollution abatement because of damaging temperature effects on dissolved oxygen resources is discounted at a rate of 17 per cent per cfs to allow for these losses.

WATER SUPPLY - QUANTITY

Benefits assignable to water storage and low flow increases for water supply exist in four locations and would apply to five different uses along the North Branch. Referring to Figure 36, it is seen that additional water for various uses will be required in various areas as follows: Luke area - municipal, industrial processing, industrial cooling, and make-up water; upstream Cumberland area - steam-electric cooling and make-up water; Cresaptown area - industrial processing, industrial cooling, and make-up waters; Cumberland area - municipal supply.

Benefits assignable to proposed upper basin storage would be equivalent to the least costly alternate supply or method, depending upon the particular uses that would be developed or provided by each local entity to satisfy the particular needs.

For the purposes of this evaluation, it is assumed that each entity would be the first to develop the potentials presently in existence in the region, to the extent required to meet individual needs.

An evaluation of the most economical development plan for single purpose water supply storage in the Upper North Branch to meet individual needs downstream, reveals that for municipal water the annual benefit per cfs would be $10,600, assuming amortization over a 50-year period at 4 per cent.[1] This value would apply to municipal uses in the Luke area only. For industrial processing and make-up water, the estimated annual benefit per cfs is $14,000, assuming amortization over a 50-year period at 6 per cent. To determine the benefit assignable to proposed storage for municipal supply at Cumberland where North Branch water could not be used, costs were estimated for several alternate single purpose reservoirs with pipelines to Cumberland. It was found that further development of Evitts Creek would be the least costly alternate. In estimating the cost of a pipeline between the existing Savage Reservoir (water to be replaced from the Upper proposed Savage Reservoir) and Cumberland, it is found that the pipeline would involve less expense

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1 - Developed by Washington District, Corps of Engineers at the request of, and in consultation with the Public Health Service.

NORTH BRANCH POTOMAC RIVER
ANNUAL POLLUTION ABATEMENT BENEFITS
INTERSTATE COMMISSION D.O. OBJECTIVE
AND CONTROL OF COLOR AND PERSISTANT CHEMICALS

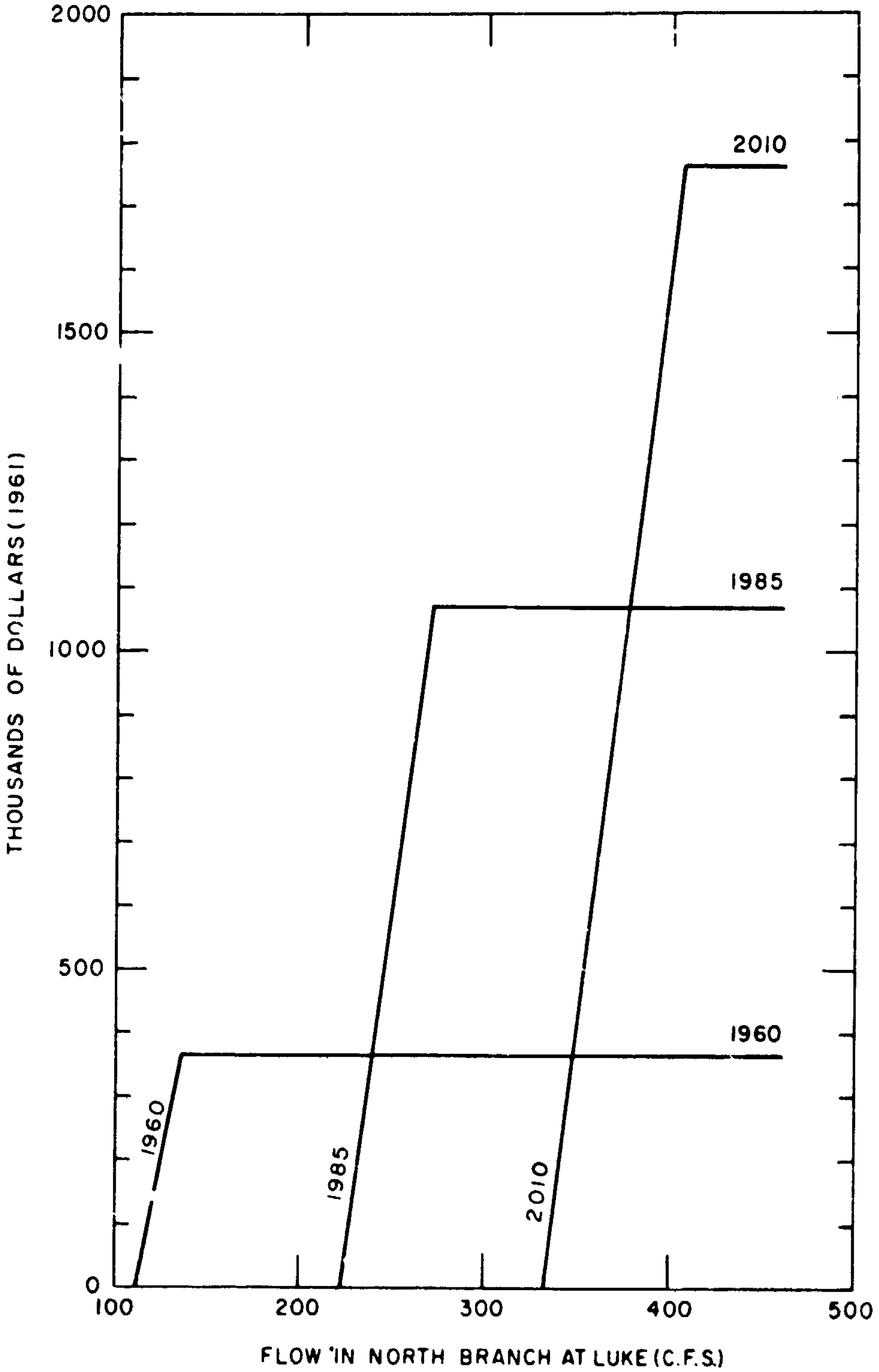

FIGURE 35

NORTH BRANCH POTOMAC RIVER
WATER USES AND REQUIREMENTS
1960-2010

LEGEND

Luke Area
A-1 Pollution Abatement only
A-2 Municipal Water Supply
A-3 Industrial Processing
A-4 Industrial Cooling and Pollution Abatement

Upstream Cumberland
B Steam-Electric

Cresaptown Area
C-1 Industrial Processing
C-2 Industrial Cooling

Cumberland Area
D Municipal Water Supply

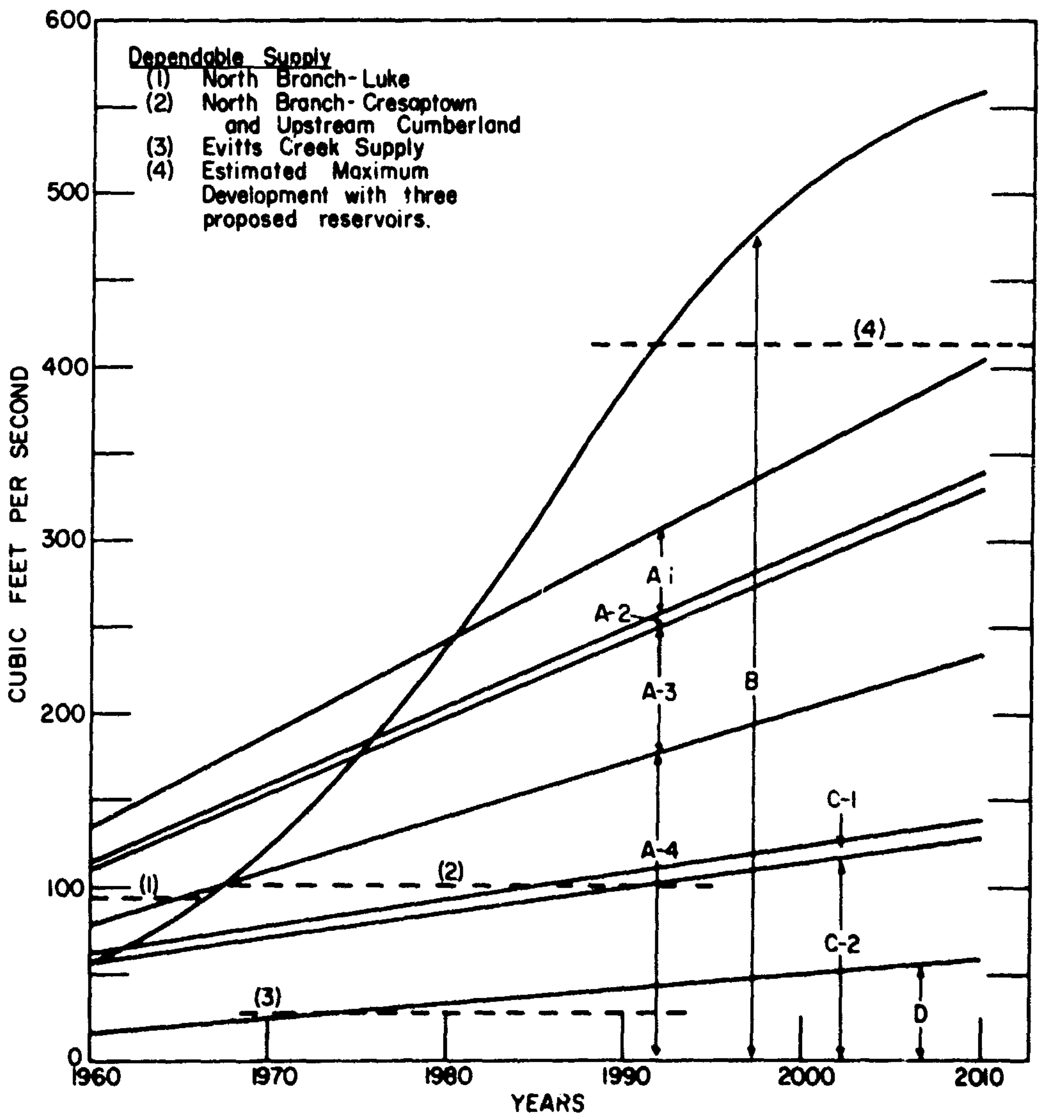

FIGURE 36

than development of the required additional storage capacity and transmission cost (29 cfs) from Evitts Creek. The difference in cost and, therefore, the annual benefit assignable to the proposed Savage Reservoir for municipal water supply at Cumberland is $7,100 per cfs assuming amortization over a 50-year period at 4 per cent.[1]

Benefits assignable to increased stream flow for industrial cooling in the Luke and Cresaptown areas and for steam-electric power production upstream from Cumberland are estimated by use of costs to provide similar cooling capacity with cooling towers. The annual benefit established for this use at each location is $1,800 per cfs.[2] This value is not considered firm for every case since values vary according to design and operation. It is also recognized that evaporation would be greater with cooling tower operation than river operation. Therefore, benefits applicable to consumptive uses could be determined as the cost to replace the difference in amounts of water consumed in cooling tower and river operation. The assigned annual values for this use would range from $10,600 to $14,000 per cfs, depending upon which rate of interest the user would be required to pay for construction financing.

With respect to the 250,000 KW thermal power plant anticipated for 1985 above Cumberland, the value of low flow augmentation (150 cfs) or 250 cfs required at that point can be determined somewhat more accurately than by use of the $1,800 per cfs figure previously discussed for the value of cooling water.

Assuming that about one-half gallon per minute is required per KW for cooling, the following computation is made. At an installed cost of approximately $8.00 per KW for cooling towers, the capital cost for 250,000 KW is about $2,000,000. According to a manufacturer regularly engaged in this field, the useful life of a cooling tower is about 11 years and the annual operation and maintenance cost amounts to about 5 per cent of the capital cost. Amortization, with an interest rate of 5 per cent which a utility system might pay, with an additional cost for operation and maintenance, produces an annual cost of approximately $340,000.[3] This value might be partially reduced depending upon operating time; however, costs such as fixed charges, maintenance and fire protection are continuous.

In addition to amortization, operation and maintenance costs for cooling towers, an additional consumptive use of water over river operation would result. Due principally to evaporation, make-up water would be approximately 6 cfs for 250,000 KW. Assuming that the difference in evaporation between cooling tower and river operation is 3 cfs, the equivalent annual replacement benefit assignable

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1 - Washington District, Corps of Engineers at request of the Public Health Service.

2 - Electric World - July, 1955; data adjustment to North Branch Temperature frequencies and 1961 ENR by Washington District, Corps of Engineers.

3 - May 1959 Cost Data.

to increased low flow for consumptive use with cooling towers would be approximately $12,500 per cfs (5 per cent interest)[1] or $37,500. Therefore, the total annual benefit assignable to a flow of 250 cfs for 250,000 KW is equivalent to annual cooling tower costs of $377,500, reduced somewhat for non-use periods.

It is recognized that water losses occur to various extents for the diverse uses in the North Branch region; however, no attempt is made at this time to evaluate these losses, since to do so would require intensive study which time does not permit.

All benefits are limited to time periods and quantities of use as indicated in Figure 36. Apportioning of benefits for various uses and to various proposed reservoir projects can be made as necessary to establish the most suitable over-all multi-purpose plan for the North Branch.

DISCUSSION

Owing to the character and abundance of raw materials in existence in the Appalachian Mountain region of the North Branch Potomac River Basin, extensive industrial development has occurred and there are sufficient potential reserves in the region to support greater development into the future.

Coal, wood, and water constitute the basic essentials necessary for promotion of industrial activities in the region. The excellent transportation facilities and convenience to markets also make the area attractive to industrial interests.

Whereas coal and timber reserves are available in relatively great abundance, dependable supplies of water to meet anticipated future demands are not yet developed. The fact that all of the minimum flow of the North Branch is used for pulp and paper production, and that downstream industrial, steam-electric, and municipal water requirements will exceed existing dependable supplies at various times in the future, indicates the need for future development of water supplies with provisions for water quality control. This also indicates to what extent expenditures to implement such development would be required.

As pointed out previously, water requirements for pulp and paper manufacture would be expected to increase directly with increases in production capacity. It could not be assumed that less water would be used per unit of pulp and paper production in the future, since re-use factors involved in recycling water of various qualities to various stages of the process are limited and are considered to be in constant balance. Therefore, expenditures involved

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1 - Derived from Cost Data developed by Washington District, Corps of Engineers for North Branch Potomac - 1961.

in expanding pulp and paper production to three times present capacity on the North Branch would include costs to increase production and chemical recovery capacities, costs to develop reservoir storage to provide total stream flow equal to three times the present minimum flow, and costs for additional activated sludge treatment facilities to conform with increases in production. Also, since dilution flows in the stream are an indispensable part of waste treatment, an additional increment of flow, over and above that used for pulp and paper production, should be included in reservoir design.

In view of these requirements and in keeping with water quality objectives previously described for the North Branch, i.e., the control of dissolved oxygen levels for general sanitation, the prevention of nuisance conditions locally, and the control of colored wastes and persistent chemicals for protection of downstream Potomac River quality, the possibility that a portion of the anticipated future pulp and paper production would be located in another Appalachian Mountain region adjacent to the North Branch is presented. Only one region, that of the South Branch Potomac, would offer such a potential site for this purpose. It is estimated, however, that to protect the quality of main stem Potomac waters in a manner consistent with North Branch objectives, would require that a site on the South Branch be no further downstream than about the vicinity of Petersburg, West Virginia. However, natural stream flows in this area would only be sufficient to support a pulp and paper mill of less than one-quarter of the capacity of the present mill at Luke, or less than 200 tons of pulp per day. Maximum treatment of wastes would be required and greater production capacity would necessitate development of storage for water supply and dilution of treated wastes in the South Branch. Therefore, costs per unit increases in pulp and paper production in the Petersburg area would be expected to equal or exceed those involved in the Luke area, especially when considering added transportation and related operational costs. The desirability of degrading water quality of the South Branch to alleviate further pollution of the North Branch is also problematical. A decision of this kind would be within the jurisdiction of State, interstate, and local authorities.

Continuous monitoring or frequent surveillance of the North Branch should be undertaken to keep abreast of conditions and to provide knowledge on measures that might be applied to improve water quality control. This would be especially important in the event that storage is provided for water supply and low flow augmentation on the North Branch upstream from the Luke area.

An impoundment on the North Branch should include multi-level outlets in the dam structure to control releases of water from various depths for maximum utilization of temperature and dissolved oxygen. Since temperature stratification would be expected within the reservoir, withdrawals of low temperature water from lower levels would be desirable for cooling uses downstream. The greater

the depths, however, the lower the dissolved oxygen concentrations may become due to the oxidation of unstable organic matter and slower atmospheric reaeration rates at these lower levels. Such waters are of little value in assimilating oxygen demanding wastes downstream. For reservoir storage to be effective in providing temperature reduction and pollution abatement benefits downstream, releases should be controlled from levels which provide an optimal balance between temperature and dissolved oxygen concentrations. Continuous or frequent monitoring of temperature and dissolved oxygen by depth would indicate from which level waters should be released to maintain this balance. Downstream surveillance of stream conditions during augmentation periods would supply information on the effectiveness of low flow increases in abating the pollutional effects of wastes.

As was indicated in an earlier section of this report, water losses by various users have purposely been omitted from evaluations, since time does not permit such studies. Cooling water losses, in terms of make-up water, have been dealt with briefly since these are believed to constitute a significant loss. It is recognized that water is consumed in pulp and paper making, both in the drying process and retention in the paper. Most of the wash water and wringer water would be expected to be returned to the stream. Small and relatively insignificant losses would be expected in the processing of chemicals. Losses in cooling water associated with this process have been indicated. Consumption of water in the municipal system can be appreciable percentage-wise, perhaps up to 10 per cent.

The method by which benefits have been computed, i.e., where uses and purposes are dealt with as separate unrelated entities, serve to illustrate how each purpose would benefit from the proposed water storage in terms of costs to supply individual needs, and to satisfy similar requirements and objectives in the absence of the project.

Care should be exercised in the addition of benefits. It should be recognized that in several instances certain benefits would not be additive. For example, benefits from acid reduction for pollution abatement and water supply would be additive when computing benefits. However, for use in cost apportionment, only the benefit to water supply from acid reduction has an identifiable beneficiary. The benefit to pollution abatement resulting from acid reduction would be a widespread benefit. Total costs allocated to acid reduction may not exceed the benefit to pollution abatement from acid reduction.

Temperature reduction benefits apply only to improved cooling efficiencies in the Luke area. These benefits would be additive in benefit computations.

The separate benefits shown for control of dissolved oxygen, reduction of biochemical oxygen demand concentrations, and control of color and persistent chemicals are not additive. Since the

objective for control of dissolved oxygen, and color and persistent chemicals can only be achieved with combined activated sludge treatment and low flow augmentation, the benefit shown for color and persistent chemical control which includes dissolved oxygen control and biochemical oxygen demand reductions would apply. Should it be desired to differentiate between costs to control dissolved oxygen and persistent chemicals, these values may be compared. The value of dilution flows in terms of theoretical treatment costs to achieve similar reductions in biochemical oxygen demand concentrations is of no particular significance in this instance, except that it expresses the order of magnitude to which augmentation flow values for reducing this pollution parameter applies. It is again emphasized that without improved pulp and paper waste treatment techniques and dilution flows far in excess of estimated maximum storage development in the North Branch, the Interstate Commission, Class D biochemical oxygen demand objective cannot be achieved.

For gross analysis of water supply benefits, values, as previously described, are additive. However, it is apparent that proposed storage and increased stream flows may be used more than once for various purposes. In the event, reimbursements assignable to a given volume of water should be divided between respective users in a manner consistent with values established for each use. Such apportionment would apply to all re-uses downstream, including Hagerstown, Maryland, and Washington, D. C. Values to these latter users are not yet computed by this agency, but will be included in the over-all Potomac Basin evaluation. In apportioning values to various downstream users, allowances should be made for the particular water quality that would result from respective upstream uses.

It is understood that all costs shown in this report will be adjusted to an appropriate Engineering News Record index, and that all benefits will be discounted to present worth from the respective times of use.

The Public Health Service is not in a position to state that pulp and paper production of the magnitude predicted will of necessity or reality all be located on the North Branch of the Potomac River. Such a decision will be made by the interested State agencies in the areas of possible production, based on many factors not within the scope of this report. The purpose of the report is only to determine the value of water to industries which may locate on the North Branch of the Potomac.

The fact that the anticipated increases in pulp and paper production, coupled with present knowledge of waste treatment would result in stream quality inconsistent with objectives established by the Interstate Commission on the Potomac, should not be interpreted either as endorsing heavy development on the North Branch, or as suggesting that the Interstate Commission objectives are unnecessarily high. The intent of the report is to be as factual as possible and to present anticipated effects based on the best knowledge and judgment of factors relating to the scope of designated responsibilities.

PART IV

APPENDIX

TABLE A-1

INDIVIDUAL RESULTS OF SAMPLING OF THE NORTH BRANCH AND ITS TRIBUTARIES

Station	Date	Time	Temp (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/day	C.O.D. (ppm)	C.O.D. #/day	Solids (ppm) Total (w/o Set.S.)	Settleable (p = 1.25)	Total Fixed	Total Volatile	Total Suspended	Total Suspended Fixed	Total Suspended Volatile	Total Dissolved	Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm) Phen. (M.O.)	Total (Total)	Dissolved Fe (ppm)	Dissolved Fe++ (ppm)	Dissolved Mn (ppm)	Tannin & Lignin (ppm)	Sulfate (ppm)
1 - 1	9-18	8:05 A	12	4.5	7.46	0.22	5.3	-	-	-	3100	-	-	-	-	-	-	12	3.8	(27.0)	(56.0)	-	-	-	-	-
2	9-21	8:50 A	6	5.5	8.70	0	0	-	-	980	2500	240	740	-	-	-	-	95	3.7	(43.0)	(134.5)	-	-	-	-	-
3	9-24	9:00 A	13	4.6	6.47	1.0	25	-	-	-	7500	-	-	-	-	-	-	27	3.7	(28.5)	(84.0)	-	-	-	-	-
4	9-27	9:10 A	8	5.0	7.09	4.1	111	-	-	1280	3100	400	880	570	80	490	710	68	3.3	(66.0)	(376.0)	-	-	-	-	-
5	10-3	7:45 A	12	4.0	5.56	5.1	110	-	-	2600	6800	660	1940	2282	1083	1199	318	25	3.3	(66.5)	(145.5)	-	-	-	-	-
6	10-10	7:45 A	6	6.0	9.02	0.8	25.9	-	-	360	4600	120	240	11.2	3	8.2	349	47	3.6	(31.0)	(99.5)	-	-	-	-	-
7	10-18	8:10 A	9	4.2	[illegible]	3.2	72.6	-	-	3180	9800	420	2760	2749	1463	1296	431	38	3.7	(24.0)	(89.0)	-	-	-	-	-
8	10-23	7A→2:30P	-	4.0	-	-	-	-	-	2580	13500	650	1930	2445	1245	1200	135	-	-	-	-	-	-	-	-	-
2 - 1	9-18	8:00 A	13	(1)60	8.90	0.36	117	-	-	-	1000	-	-	-	-	-	-	5	3.7	(21.5)	(51.0)	-	-	-	-	-
2	9-21	8:45 A	6	(1)25	9.84	0	0	-	-	520	0	340	180	-	-	-	-	16	3.6	(46.5)	(121.5)	-	-	-	-	-
3	9-24	9:50 A	14	(1)32	8.88	0.3	52	-	-	-	-	-	-	-	-	-	-	16	3.4	(58.5)	(120.5)	-	-	-	-	-
4	9-27	9:05 A	9	(1)26	9.95	1.2	168	-	-	480	0	300	180	-	-	-	-	20	3.5	(57.5)	(116.5)	-	-	-	-	-
5	10-3	7:35 A	12	(1)15	8.80	0.3	24	-	-	620	0	380	240	6	2	4	614	14	3.2	(72.0)	(129.0)	-	-	-	-	-
6	10-10	8:30 A	6	(1)49	10.24	0.41	108	-	-	140	0	40	100	4.7	0	4.7	135	10	3.8	(18.0)	(51.5)	-	-	-	-	-
7	10-18	8:00 A	9	(1)26	9.83	0.66	92	-	-	340	0	100	240	10	4	6	330	24	3.1	(55.0)	(120.0)	-	-	-	-	-
3 - 1	9-18	8:20 A	12	(1)66	8.69	0.22	78.4	-	-	-	1100	-	-	-	-	-	-	5	3.7	(20.5)	(52.0)	-	-	-	-	-
2	9-21	8:30 A	6	(1)30	9.85	0.1	16.2	-	-	480	0	280	200	-	-	-	-	17	3.7	(40.5)	(111.5)	-	-	-	-	-
3	9-24	8:40 A	14	(1)37	8.24	0.9	180	-	-	-	-	-	-	-	-	-	-	15	3.4	(56.0)	(114.0)	-	-	-	-	-
4	9-27	8:55 A	9	(1)31	9.41	1.3	218	-	-	460	0	260	200	-	-	-	-	21	3.5	(58.5)	(119.0)	-	-	-	-	-
5	10-3	7:15 A	13	(1)24	7.95	0.1	13.0	-	-	560	0	360	200	14	7	7	546	24	3.5	(47.0)	(110.5)	-	-	-	-	-
6	10-10	7:35 A	6	(1)54	9.89	0.02	5.83	-	-	140	0	40	100	16.1	.7	15.4	124	39	3.9	(11.5)	(49.0)	-	-	-	-	-
7	10-18	7:45 A	10	(1)30	9.40	0.65	205	-	-	300	0	80	220	33.5	7.4	26.1	266	14	3.2	(19.0)	(95.0)	-	-	-	-	-
4 - 1	9-18	8:55 A	13	(2)1.6	9.48	1.08	9.4	-	-	-	0	-	-	-	-	-	-	37	7.5	-	10.9	0.40	-	0.24	-	-
2	9-21	9:15 A	7	(2)1.6	10.25	0.90	7.8	-	-	220	0	140	80	-	-	-	-	34	6.0	-	10.5	0.58	0.04	0.09	-	-
3	9-24	9:20 A	14	(2)26	8.66	0.70	98	-	-	-	-	-	-	-	-	-	-	48	7.5	-	9.5	0.84	0.07	0.17	-	-
4	9-27	9:35 A	8	(2)26	9.68	0.60	84	-	-	100	0	60	40	21	11	10	79	50	5.9	-	9.0	1.46	0.14	0.16	-	-
5	10-3	8:30 A	14	(2)26	8.88	0.5	70	-	-	240	0	200	40	11.6	2.4	9.2	228	45	7.2	-	9.5	0.75	-	0	-	0.81
6	10-10	8:15 A	8	(2)150	9.94	1.46	1200	-	-	160	0	60	100	11.4	4.0	7.4	149	47	4.5	(-)	(11.0)	-	-	-	-	2.2
7	10-18	8:30 A	10	(2)10	9.46	0.43	23	-	-	40	0	20	20	21.4	10.7	10.7	19	33	6.6	-	7.5	-	-	-	-	0.64
5 - 1	9-18	9:10 A	14	196	8.97	0.36	381	-	-	-	400	-	-	-	-	-	-	4	3.9	(10.5)	(52.0)	0.62	-	0.64	-	-
2	9-21	7:45 A	8	90	10.16	0.8	389	-	-	280	0	220	60	-	-	-	-	3	4.5	-	(25.0)	0.95	0.12	0.70	-	-
3	9-24	7:45 A	15	128	8.82	0.60	415	-	-	-	-	-	-	-	-	-	-	6	4.5	-	29.5	0.88	0.03	0.43	-	-
4	9-27	8:00 A	10	120	9.66	1.4	907	-	-	200	0	120	80	-	-	-	-	10	4.5	-	7.0	0.97	0.12	0.47	-	-
5	10-3	6:35 A	12	110	9.11	0.8	475	-	-	280	0	220	60	3.6	0.8	2.4	276	7	4.3	(1.5)	(20.5)	0.94	-	0.47	-	-
6	10-10	6:45 A	9	318	10.25	0.86	1480	-	-	40	0	0	40	5.4	2.0	3.4	35	14	4.9	-	8.5	0.52	-	0.48	-	2.8
7	10-18	7:00 A	10	122	9.60	0.63	415	-	-	80	0	40	40	6.0	1.6	4.4	74	4	4.3	(3.5)	(18.0)	0.19	-	0.31	-	5.7
6 - 1	9-18	9:50 A	16	195	9.23	0.90	948	-	-	-	0	-	-	-	-	-	-	6	3.8	(10.5)	(37.0)	0.49	-	0.88	-	-
2	9-21	10:10 A	11	89	10.29	0.6	288	-	-	300	0	260	40	-	-	-	-	8	4.05	(8.0)	(34.0)	1.41	0.23	0.78	-	-
3	9-24	11:25 A	18	117	8.99	0.20	126	-	-	-	-	-	-	-	-	-	-	0	4.0	(8.5)	(38.0)	1.17	0.08	0.88	-	-
4	9-27	11:40 A	12	113	9.91	2.7	1648	-	-	280	0	220	60	14	9	5	260	4	4.2	(11.5)	(38.5)	1.52	0.26	0.76	-	-
5	10-3	10:45 A	17	111	9.08	1.3	779	-	-	300	0	260	40	4.4	1.6	2.8	296	8	4.2	(5.0)	(29.0)	1.19	-	1.0	-	-
6	10-10	10:50 A	12	392	10.11	0.77	1630	-	-	100	0	40	60	9.4	5.4	4.0	91	11	4.6	-	6.0	1.30	-	0.69	-	-
7	10-18	11:05 A	14	132	9.29	2.01	1433	-	-	140	0	80	60	6.8	3.2	3.6	133	2	4.2	(6.0)	(25.0)	0.08	-	0.13	-	-

(1) Estimated from Discharges at Steyer (Gage recently installed by U.S.G.S.)
(2) Discharges from Stony River Dam.

TABLE A-1

INDIVIDUAL RESULTS OF SAMPLING OF THE NORTH BRANCH AND ITS TRIBUTARIES

Station	Date	Time	Temp (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/day	C.O.D. (ppm)	C.O.D. #/day	Solids (ppm): Total (w/o Set.S.)
7 - 1	9-16	9:55 A	11	121	10.46	0.62	405	-	-	-
2	9-21	11:25 A	11	121	10.40	0.9	588	-	-	180
3	9-24	11:30 A	14	119	9.73	1.0	643	-	-	-
4	9-27	11:45 A	12	119	10.03	0.6	386	-	-	100
5	10-3	10:45 A	16	117	9.26	1.6	101	-	-	22[illegible]
6	10-10	11:05 A	14	116	9.88	0.74	464	-	-	4
7	10-18	11:05 A	14	114	9.58	0.5	308	-	-	60
8 - 1	9-18	10:35 A	13	14	9.71	1.02	77.1	-	-	-
2	9-21	10:50 A	8	10	10.82	0.7	37.8	-	-	100
3	9-24	10:50 A	15	11	9.47	0.8	47.5	-	-	-
4	9-27	11:00 A	10	7.7	10.16	0.5	20.8	-	-	180
5	10-3	10:00 A	14	6.2	9.51	0.4	13.4	-	-	140
6	10-10	10:15 A	8	21	11.01	0.4	45.4	-	-	20
7	10-18	10:15 A	11	14	10.04	0.4	30.2	-	-	20
6 - 01	9-19	8:35 A	14	153	9.48	0.77	636	8.23	6800	-
02	9-25	9:10 A	14	141	9.35	1.0	761	10.1	7690	-
03	10-1	8:20 A	14	143	9.20	0.6	463	9.64	7440	-
04	10-4	8:10 A	17	228	8.27	0.4	493	7.3	8990	420
05	10-8	6:35 A	10	618	9.91	0.5	1670	26.6	88800	120
06	10-11	9:45 A	8	356	9.36	0.55	1060	7.80	15000	100
07	10-15	7:10 A	10	271	9.90	0.9	1320	7.41	10800	100
7 - 01	9-19	8:45 A	10	121	10.40	1.02	667	5.10	3330	-
02	9-25	9:00 A	12	119	10.05	1.1	707	3.88	2490	-
03	10-1	8:30 A	13	117	9.71	1.2	758	5.02	3170	-
04	10-4	8:30 A	15	117	8.92	1.0	632	13.5	8530	200
05	10-8	6:45 A	11	116	9.71	0.1	62.6	3.98	2490	60
06	10-11	9:00 A	11	116	10.22	0.6	376	5.85	3660	60
07	10-15	7:20 A	12	114	9.73	0.7	431	4.29	2640	80
9 - 1	9-19	8:20 A	16	274	2.10	18.9	28000	87.8	130000	320
2	9-25	8:50 A	17	260	5.96	30.3	42500	140.8	198000	360
3	10-1	8:45 A	17	260	6.40	23.6	33100	103.9	146000	500
4	10-4	8:40 A	20	345	6.90	26.0	48400	125.8	234000	660
5	10-8	7:15 A	11	734	9.15	5.6	22200	37.3	148000	140
6	10-11	7:45 A	10	472	9.28	20.0	51000	53.8	137000	180
7	10-15	6:45 A	14	385	8.25	15.5	32300	70.6	147000	180
8	10-18	4:30 P	20	246	-	36.8	48900	165.6	220000	340
10 - 1	9-19	8:55 A	11	20	9.92	6.4	691	10.6	1150	600
2	9-25	9:55 A	12	15	9.80	1.3	105	10.5	851	740
3	10-1	8:00 A	12	15	9.58	3.6	292	11.6	940	720
4	10-4	7:35 A	16	40	8.51	2.3	497	61.4	13300	1340
5	10-8	6:20 A	9	29	10.31	1.0	157	7.94	12400	400
6	10-11	8:[illegible] A	8	19	10.11	2.3	236	8.97	9200	540
7	10-15	6:55 A	14	16	10.13	0.8	69.1	7.80	6740	720
10A- 1	9-19	9:15 A	10	16	9.42	7.1	613	-	-	-
2	9-25	9:30 A	11	11	9.88	0.5	30	-	-	-
3	10-1	7:40 A	11	11	9.44	1.0	59	-	-	580
4	10-4	7:15 A	15	35	8.50	4.7	850	-	-	660
5	10-10	11:30 A	10	25	10.16	1.6	216	4.36	589	420
6	10-11	8:00 A	8	15	11.11	1.6	130	3.51	284	460
7	10-18	11:30 A	14	12	9.11	0.6	39	12.9	836	520

Station	Date	Solids (ppm): Settleable (p = 1.25)	Total Fixed	Total Volatile	Total Suspended	Total Suspended Fixed	Total Suspended Volatile	Total Dissolved	Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm): Phen. (M.O.)	Total (Total)	Dissolved Fe (ppm)	Dissolved Fe++ (ppm)	Dissolved Mn (ppm)	Tannin & Lignin (ppm)	Sulfate (ppm)
7 - 1	9-16	0	-	-	-	-	-	-	6	7.[illegible]	-	13.0	0.77	-	0.13	-	-
2	9-21	0	140	40	-	-	-	-	20	8.7	2.0	22.0	0.16	0.02	0.[illegible]8	-	-
3	9-24	-	-	-	-	-	-	-	12	7.4	-	17.0	0.19	0	0.18	-	-
4	9-27	0	60	40	3.[illegible]	2.0	1.2	97	13	6.5	-	18.0	0.22	0.04	0.12	-	-
5	10-3	0	140	80	7.2	1.2	6.0	213	15	8.0	-	18.0	0.51	-	0.27	-	-
6	10-10	0	0	40	6.0	0	6.0	34	18	6.9	-	18.5	0.21	-	0.45	-	-
7	10-18	0	20	40	11.2	7.6	3.6	49	11	7.3	-	18.5	-	-	0.08	-	-
8 - 1	9-18	0	-	-	-	-	-	-	10	7.2	3.5	15.5	0.07	-	-	-	-
2	9-21	0	60	40	-	-	-	-	23	6.6	-	20.0	0.15	0.06	0.07	-	-
3	9-24	-	-	-	-	-	-	-	17	7.1	-	18.5	0.08	0.02	0.26	-	-
4	9-27	0	40	140	7.2	4.8	2.4	173	10	6.4	-	21.5	0.07	0.[illegible]	0.37	-	-
5	10-3	0	140	0	8.8	2.0	6.8	131	10	6.[illegible]	-	20.5	0.08	-	0	-	-
6	10-10	0	0	20	.7	0	.7	19.3	18	7.0	-	18.5	-	-	-	-	-
7	10-18	0	0	20	2.4	1.6	.8	18	8	7.2	-	18.5	-	-	-	-	-
6 - 01	9-19	-	-	-	-	-	-	-	0	4.3	(4.0)	(26.3)	-	-	-	0.2	-
02	9-25	-	-	-	-	-	-	-	1	4.1	(0.6)	(31.0)	-	-	-	0.2	9.4
03	10-1	-	-	-	-	-	-	-	0	4.2	(3.5)	(23.0)	-	-	-	0.75	4.8(?)
04	10-4	0	280	140	19.3	7.3	12.0	401	2	4.0	(10.0)	(38.0)	-	-	-	0.3	11.4
05	10-8	0	20	100	21.4	10.7	10.7	99	6	4.6	-	(13.0)5.0	1.59	-	0.62	0.8	4.3
06	10-11	0	60	40	9.2	2.8	6.4	94	8	4.[illegible]	-	(14.0)6.5	-	-	-	0.35	4.7
07	10-15	0	60	40	6.8	1.2	5.6	93	3	4.5	-	(16.5)4.5	0.59	-	0.45	0.2	5.3
7 - 01	9-19	-	-	-	-	-	-	-	7	7.9	-	14.5	-	-	-	0.25	-
02	9-25	-	-	-	-	-	-	-	14	7.8	-	20.5	-	-	-	0.25	0.[illegible]8
03	10-1	-	-	-	-	-	-	-	13	7.5	-	20.5	-	-	-	0.50	-
04	10-4	0	180	20	35.5	20.1	15.4	164	14	6.5	-	15.5	-	-	-	0.45	-
05	10-8	0	0	60	4.8	0	2.4	55	12	7.0	-	18.0	-	-	-	0.3	1.2
06	10-11	0	40	20	7.2	2.4	7.2	53	14	7.0	-	21.5	-	-	-	0.3	1.4
07	10-15	0	40	40	7.6	2.0	5.6	72	10	7.3	-	20.0	-	-	-	0.3	1.4
9 - 1	9-19	6000	280	40	-	-	-	-	18	10.5	58.0	122.0	-	-	-	5.5	-
2	9-25		140	220	76.8	20.4	56.4	283	204	5.8	-	17.0	-	-	-	8.6	8.[illegible]
3	10-1		100	400	60.3	10.1	50.2	440	99	5.0	-	7.0	-	-	-	8.5	8.4
4	10-4	0	400	260	170	88	82	490	93	9.6	17.0	138.0	-	-	-	3.5	7.1
5	10-8	0	40	100	34.2	14.7	19.5	106	32	6.3	-	9.0	-	-	-	1.7	4.1
6	10-11	0	20	160	51.6	16.8	34.8	128	49	6.8	-	21.0	-	-	-	1.6	4.5
7	10-15	0	140	40	54.3	19.4	34.9	126	63	6.9	-	18.0	-	-	-	2.7	4.9
8	10-18	0	120	220	75.7	22.8	52.9	264	250	7.6	-	38.5	0.95	-	0.46	12.5	6.6
10 - 1	9-19	300	530	70	-	-	-	-	1	4.3	(5.0)	(36.0)	-	-	-	1.5	-
2	9-25	0	560	180	9.6	5.6	4.0	730	5	4.0	(8.0)	(47.0)	-	-	-	0.8	45.3
3	10-1	0	560	160	14.4	2.8	11.6	706	5	4.3	(3.5)	(39.0)	-	-	-	1.6	45.6
4	10-4	0	920	420	283	225	58	1057	20	3.7	(29.5)	(94.0)	-	-	-	0.7	52.7
5	10-8	0	240	160	10.7	4.7	6.0	389	1	4.7	-	6.0	-	-	-	[illegible].7	27.8
6	10-11	0	280	260	12.7	3.4	9.3	527	8	4.9	-	10.0	-	-	-	0.6	33.9
7	10-15	0	480	240	12.1	3.4	8.7	708	2	4.3	(5.0)	(43.0)	-	-	-	0.2	40.3
10A- 1	9-19	-	-	-	-	-	-	-	2	7.8	-	15.0	-	-	-	-	-
2	9-25	-	-	-	-	-	-	-	5	7.6	-	15.5	-	-	-	-	-
3	10-1	0	440	140	11.2	4.0	7.2	569	1	6.7	-	20.0	-	-	-	-	35.5
4	10-4	0	520	140	109	67	42	551	9	6.4	-	20.5	-	-	-	-	26.4
5	10-10	0	280	140	6.7	1.3	5.4	413	17	6.7	-	18.5	-	-	-	-	25.3
6	10-11	0	260	200	20.8	7.3	13.5	439	9	6.6	-	19.5	-	-	-	-	26.5
7	10-18	0	280	240	15.2	9.6	14.6	505	5	6.7	-	14.0	0.37	-	-	-	32.5

TABLE A-1

INDIVIDUAL RESULTS OF SAMPLING OF THE NORTH BRANCH AND ITS TRIBUTARIES

Station	Date	Time	Temp (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/day	C.O.D. (ppm)	C.O.D. #/day	Solids (ppm) Total (w/o Set.S.)	Settleable (p = 1.25)	Total Fixed	Total Volatile	Total Suspended	Total Suspended Fixed	Total Suspended Volatile	Total Dissolved	Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm) Phen. (M.O.)	Total (Total)	Dissolved Fe (ppm)	Dissolved Fe++ (ppm)	Dissolved Mn (ppm)	Tannin & Lignin (ppm)	Sulfate (ppm)
11 - 1	9-19	7:30 A	12	11	9.22	1.44	77.4	5.49	326	-	-	-	-	-	-	-	-	6	8.0	-	91.5	-	-	-	-	-
2	9-25	7:20 A	12	6.3	9.36	1.1	37.4	12.03	409	-	-	-	-	-	-	-	-	9	7.8	-	104.5	-	-	-	-	-
3	10-1	6:55 A	12	8.4	8.44	1.4	63.5	5.02	228	180	0	80	100	12.8	4.8	8.0	167	7	8.0	-	103.5	-	-	-	-	-
4	10-4	6:30 A	16	32	6.74	3.2	553	19.3	3340	440	0	320	120	102.5	85.8	16.7	337	32	7.3	-	88.0	-	-	-	-	-
5	10-10	9:30 A	9	16	11.40	0.54	46.7	1.4	130	140	0	60	80	3.6	1.6	2.0	136	10	-	-	-	-	-	-	-	-
6	10-11	9:30 A	7	14	12.45	1.6	121	5.46	413	160	0	20	140	10.8	5.2	5.6	149	9	7.8	-	91.5	-	-	-	-	-
7	10-18	6:15 A	12	9.2	8.21	1.4	69.4	1.96	97.4	180	0	20	160	6.8	6.4	0.4	175	9	7.8	-	100.0	-	-	-	-	-
12 - 1	9-19	8:05 A	14	*305	7.25	16.7	27500	61.5	101000	240	2500	140	100	-	-	-	-	60	7.7	-	16.0	0.49	-	0.46	3.6	-
2	9-25	7:30 A	16	297	5.86	20.1	32200	108.3	174000	320	0	180	140	78.8	18.8	60.0	241	102	6.5	-	23.0	0.89	0.34t	0.58	6.1	-
3	10-1	7:05 A	16	297	4.82	15.5	24900	66.4	106000	280	2800	160	120	35.2	8.4	26.8	245	108	7.1	-	33.0	0.86	-	2.28(?)	9+	-
4	10-4	6:50 A	20	608	2.40	3.1	6800	117.7	259000	580	0	400	180	82.4	33.5	48.9	458	122	9.2	13.0	99.5	0.68	-	0.42	5.9	-
5	10-8	6:00 A	12	809	8.37	12.3	53700	48.0	210000	180	0	40	140	60.3	24.1	36.2	120	46	6.9	-	18.5	-	-	-	1.9	-
6	10-11	7:30 A	10	520	7.50	24.1	67700	58.9	165000	220	0	40	180	41.5	12.7	28.8	178	94	7.3	-	41.5	-	-	-	2.3	-
7	10-15	6:25 A	13	435	7.55	11.?	26400	59.7	137000	220	0	120	100	36.2	14.1	22.1	184	78	7.2	-	23.0	-	-	-	3.3	-
13 - 1	9-19	9:30 A	15	*337	6.97	17.?	32400	35.6	64800	-	2500	-	-	-	-	-	-	35	7.7	-	18.5	-	-	-	-	-
2	9-25	10:15 A	16	328	5.56	19.3	34200	71.0	126000	280	0	80	200	-	-	-	-	78	6.6	-	26.0	-	-	-	-	-
3	10-1	10:20 A	18	328	5.47	13.4	23700	78.6	139000	280	4200	160	120	46.2	12.1	34.1	234	110	6.7	-	29.0	-	-	-	-	-
4	10-4	9:00 A	19	452	5.03	9.2	22400	99.?	144000	420	0	260	160	21.4	5.9	15.5	399	128	6.9	-	44.0	-	-	-	-	-
5	10-8	7:35 A	12	893	8.30	7.3	34700	42.1	203700	180	0	80	100	52.3	23.5	28.8	128	47	6.8	-	-	-	-	-	-	-
6	10-11	10:?0 A	12	776	8.03	17.9	55500	48.6	213000	220	0	120	100	48.9	13.4	35.5	171	100	7.3	-	36.0	-	-	-	-	-
7	10-15	7:30 A	13	469	7.40	9.0	22800	49.1	124000	220	0	100	120	31.5	11.4	20.1	128	64	7.1	-	25.5	-	-	-	-	-
14 - 1	9-19	10:20 A	16	363	5.14	10.9	21400	56.8	111000	160	0	160	0	-	-	-	-	70	7.7	-	49.0	1.0	-	0.34	3.9	-
2	9-25	10:45 A	18	259	5.56	6.1	8530	43.5	60800	300	0	140	160	62.8	15.6	47.2	237	105	6.8	-	39.0	1.52	0.28	0.81	3.8	-
3	10-1	9:45 A	16	300	6.00	8.5	13800	30.9	50100	240	0	140	100	3.6	1.2	2.4	236	76	7.1	-	36.5	1.03	-	0.57	3.1	-
4	10-4	9:30 A	20	322	5.01	9.3	16200	43.2	75100	340	0	180	160	20.8	8.7	12.1	319	122	7.0	-	44.0	1.40	-	0.72	5.4	-
5	10-8	8:15 A	12	960	7.20	6.6	33900	56.0	284000	200	0	120	80	97.8	56.3	41.5	102	42	7.0	-	29.5	0.96	-	0.49	1.8	-
6	10-11	10:30 A	12	540	8.10	11.5	33500	49.5	144000	80	0	20	60	39.5	18.1	21.4	40	77	7.2	-	33.5	-	-	-	2.3	-
7	10-15	8:30 A	14	457	6.35	5.9	14400	38.6	95300	280	0	180	100	25.5	9.4	16.1	254	60	7.2	-	36.5	0.77	-	0.49	2.1	-
Q1	9-20	7:20 A	14	279	6.48	3.9	5880	40.7	61300	200	0	160	40	-	-	-	-	61	7.0	-	31.2	-	-	-	-	-
Q2	9-26	7:40 A	14	263	6.17	5.4	7930	35.1	49900	240	0	200	40	25.6	13.2	12.4	214	98	7.1	-	36.0	-	-	-	-	-
Q3	10-8	7:30 A	14	275	5.69	4.3	6390	39.3	58400	140	0	140	0	18.1	6.7	11.4	122	96	7.0	-	35.5	-	-	-	-	-
16 - 1	9-20	7:40 A	18	**[illegible]	5.40	12.7	19300	29.4	44800	300	0	240	60	-	-	-	-	74	6.3	-	37.0	-	-	-	-	-
2	9-26	8:05 A	18	266	6.40	12.0	17200	38.6	55400	260	0	220	40	10.0	4.8	5.2	250	106	7.0	-	47.0	-	-	-	-	-
3	10-2	7:45 A	17	278	6.2?	3.5	5300	28.6	42900	340	0	340	0	42.9	29.5	13.4	297	98	7.1	-	47.5	-	-	-	-	-
4	10-8	8:30 A	13	965	7.08	4.4	33700	66.7	340700	240	0	120	120	97.2	52.9	44.3	143	44	6.9	-	24.0	-	-	-	-	-
5	10-15	10:20 A	14	460	6.90	20.6	51200	70.2	174000	220	0	180	40	34.8	14.7	20.1	185	63	6.4	-	29.5	-	-	-	-	-
17 - 1	9-20	10:25 A	14	114	9.47	3.7	2280	36.1	21000	360	0	300	60	-	-	-	-	20	6.7	-	43.0	0.02	0.01	0.44	0.18	-
2	9-26	8:35 A	13	73	8.93	4.1	1620	8.1	3190	240	0	200	40	20.0	16.0	4.0	220	11	7.4	-	45.5	0.32	0.06	0.60	0.5	-
3	10-2	8:35 A	14	58	8.83	7.5	2350	22.4	7020	440	0	440	0	221.1	201.7	20.0	199	21	7.0	-	43.5	-	-	-	neg.0	-
4	10-10	12:15 P	12	114	10.97	3.2	1970	7.54	4640	260	0	140	120	74.4	62.3	12.1	186	20	-	-	-	-	-	-	-	-
5	10-18	12:30 P	15	66	11.34	8.1	2890	9.40	3350	260	0	200	60	20.0	12.4	7.6	240	11	7.6	-	38.5	-	-	-	-	-
18 - 1	9-20	9:10 A	18	**[illegible]	2.77	13.7	21600	53.3	84000	-	-	-	-	-	-	-	-	49	6.6	-	47.0	1.40	0.23	0.46	3.85	-
2	9-26	8:25 A	20	263	0.42	9.0	12800	38.4	54500	260	0	220	40	-	-	-	-	109	7.1	-	52.5	1.44	0.25	0.81	4.3	-
3	10-2	8:20 A	18	278	1.85	4.5	6300	32.8	49200	180	0	180	0	16.8	4.0	12.8	163	66	6.9	-	47.0	1.25	-	0.83	2.9	-
4	10-8	1:00 P	15	1088	6.26	5.2	30400	26.6	155400	280	0	240	40	30.8	18.8	12.0	249	57	6.8	-	-	-	-	-	1.5	-
5	10-15	8:55 A	14	464	6.90	5.4	13600	37.1	93200	200	0	120	80	20.1	6.0	14.1	180	62	7.1	-	39.0	-	-	-	2.0	-

*Estimated from Gages at [illegible] (on [illegible] Creek)
**Estimated from Gages at [illegible] Ford and on [illegible] Creek

TABLE A-1

INDIVIDUAL RESULTS OF SAMPLING OF THE NORTH BRANCH AND ITS TRIBUTARIES

Station	Date	Time	Temp (°C)	Discharge (cfs)	D.O. (ppm)	B.O.D. (ppm)	B.O.D. #/day	C.O.D. (ppm)	C.O.D. #/day	Solids (ppm) Total (w/o Set.S.)	Settleable (p = 1.25)	Total Fixed	Total Volatile
19 - 1	9-20	8:30 A	17	406	6.90	4.3	9430	55.6	122000	280	0	180	100
2	9-26	8:55 A	18	336	6.07	5.5	9980	34.4	62400	340	0	240	100
3	10-2	9:00 A	18	336	6.10	3.3	5990	28.6	51900	240	0	220	20
4	10-8	9:45 A	14	1220	7.65	5.0	32900	25.0	164000	120	0	0	120
5	10-15	10:00 A	14	541	7.58	4.9	14300	31.2	91200	200	0	200	0
20 - 1	9-20	9:15 A	14	(3)13	8.78	0.9	63	18.42	1300	-	-	-	-
2	9-26	9:30 A	14	(3)13	8.75	1.2	84	18.1	1300	240	0	220	20
3	10-2	9:45 A	14	(3)13	9.30	1.1	77	8.1	570	120	0	100	20
4	10-10	1:50 P	12	(3)15	11.94	0.91	74	1.6	130	220	0	140	80
5	10-18	12:50 P	17	(3)14	10.90	1.3	98	5.48	410	140	0	100	40
21 - 1	9-20	8:45 A	18	430	4.97	4.5	10900	43.9	102000	440	0	340	100
2	9-26	9:10 A	18	358	3.62	5.6	10800	31.3	60900	280	0	220	60
3	10-2	9:20 A	18	358	4.19	3.6	7000	32.0	62000	280	0	240	40
4	10-8	10:00 A	14	1290	6.84	4.2	29300	26.6	185000	180	0	160	20
5	10-15	10:15 A	14	560	7.40	3.6	10900	32.4	98000	180	0	180	0
22 - 1	9-22	10:00 A	16	(4)487	6.80	2.5	6570	28.7	75500	300	0	220	80
2	9-26	9:55 A	17	(4)454	6.14	2.6	6370	27.4	67200	320	0	160	160
3	10-2	10:20 A	16	(4)510	6.75	2.0	5510	18.9	52100	260	0	220	40
4	10-8	10:40 A	15	(4)1480	8.07	3.3	26300	23.8	190000	240	0	200	40
5	10-15	11:55 A	14	(4)709	6.85	2.3	8800	22.6	86500	180	0	180	0
23 - 1	9-26	10:25 A	16	656	7.69	0.9	3180	15.8	59800	260	0	180	80
2	10-2	11:05 A	16	763	7.80	1.5	6180	17.8	73300	220	0	180	40
3	10-8	11:10 A	16	1800	7.91	1.8	17500	15.5	151000	160	0	60	100
4	10-15	11:30 A	14	905	8.30	1.5	7330	12.5	61100	160	0	160	0
CB-26-1	10/16-10/17	1 hr.	-	6.8	-	123.5	4530	-		610	-	210	370
CB-26-2	10/17-10/18	1 hr.	-	6.7	-	122.5	4430	-		440	2800	50	390
6-26-1	10/10-10/11	2 hrs.	-	354	8.82	0.96	1840	6.24	11900	140	0	80	60
6-26-2	10/15-10/16	2 hrs.	-	266	-	0.57	738	3.92	5220	140	0	120	20
6-26-3	10/18-10/19	2 hrs.	-	136	-	0.40	293	1.96	1440	120	0	20	100
7-26-1	10/10-10/11	2 hrs.	-	116	8.96	0.67	420	4.29	2690	80	0	40	40
7-26-2	10/15-10/16	2 hrs.	-	114	-	0.47	290	5.88	3620	100	0	60	40
7-26-3	10/18-10/19	2 hrs.	-	114	-	0.39	240	5.88	3620	140	0	60	80
9-26-1	10/10-10/11	1/2 hr.	-	470	8.00	21.2	53800	84.4	227000	170	0	80	90
9-26-2	10/15-10/16	1/2 hr.	-	380	-	31.6	61400	82.6	160500	300	0	200	100
9-26-3	10/18-10/19	1/2 hr.	-	290	-	24.4	32900	90.3	122000	360	0	200	160

Station	Solids (ppm) Total Suspended	Total Suspended Fixed	Total Suspended Volatile	Total Dissolved	Color (ppm)	pH	Alkalinity, ppm (Acidity, ppm) Phen. (M.O.)	Total (Total)	Dissolved Fe (ppm)	Dissolved Fe++ (ppm)	Dissolved Mn (ppm)	Tannin & Lignin (ppm)	Sulfate (ppm)
19 - 1	-	-	-	-	70	6.4	-	50.0	-	-	-	-	-
2	42.0	32.5	9.5	298	93	7.1	-	51.0	-	-	-	-	-
3	50.9	38.9	12.0	189	59	7.1	-	48.0	-	-	-	-	-
4	43.8	34.2	9.6	76	56	7.0	-	-	-	-	-	-	-
5	24.8	18.8	6.0	175	55	7.2	-	43.0	-	-	-	-	-
20 - 1	-	-	-	-	23	6.7	-	98.0	-	-	-	-	-
2	111.9	101.2	11	128	35	7.75	-	103.0	-	-	-	-	-
3	10.4	5.6	4.8	110	12	7.8	-	107.5	-	-	-	-	-
4	8.7	3.4	5.3	211	15	-	-	-	-	-	-	-	-
5	12.0	8.0	4.0	128	14	8.0	-	111.5	-	-	-	-	-
21 - 1	-	-	-	-	78	6.4	-	50.5	1.02	0.18	0.72	2.5	-
2	33	25	8	247	102	7.45	-	61.0	1.60	0.38	0.70	4.1	-
3	39.5	28.8	10.7	240	62	7.1	-	49.5	1.11	-	0.86	2.8	-
4	44.9	30.2	14.7	135	64	7.1	-	-	-	-	0.62	1.8	-
5	20.8	14.1	6.7	159	64	7.1	-	44.5	-	-	0.62	1.6	-
22 - 1	-	-	-	-	41	6.9	-	54.5	0.78	0.15	0.30	1.35	-
2	20.4	18.4	2.0	300	61	7.0	-	57.0	1.11	0.18	0.44	1.85	-
3	14.7	6.7	8.0	245	47	7.2	-	48.0	0.89	-	0.43	1.9	-
4	51.6	34.9	16.7	188	53	7.2	-	-	-	-	-	1.5	-
5	10.1	8.0	2.1	170	54	7.3	-	52.5	-	-	-	1.4	-
23 - 1	21.6	20.4	1.2	238	40	7.2	-	65.5	0.74	0.08	0.25	1.05	-
2	14.7	7.4	7.3	205	42	7.5	-	60.0	0.69	-	0.50	1.6	-
3	30.2	20.8	9.4	130	35	7.2	-	46.0	0.52	-	0.84	0.75	-
4	8.7	8.0	0.7	151	41	7.4	-	50.0	0.55	-	0.24	0.75	-
CB-26-1	169	31	138	441	88	7.5	-	157.5	-	-	-	-	-
CB-26-2	118	13	105	322	78	7.3	-	160	-	-	-	-	-
6-26-1	9.2	4.8	4.4	131	10	4.5	-	6.5	0.20	-	0.32	0.2	4.79
6-26-2	26.1	7.3	18.8	114	4	3.9	(6.5)	(20.5)	0.86	-	0.40	0.3	5.38
6-26-3	0	0	0	120	3	4.1	(5.5)	(27.5)	0.19	-	0.54	0.15	8.10
7-26-1	6.0	2.8	3.2	74	16	6.9	-	20.5	0.13	-	0.04	0.3	1.35
7-26-2	12.1	0.7	11.4	88	11	7.1	-	18.5	0.14	-	0	0.25	1.27
7-26-3	4.4	4.4	0	136	13	7.2	-	18.5	0.09	-	0.10	0.3	1.33
9-26-1	87.7	22.3	45.4	102	92	6.9	-	23.75	0.49	-	0.43	2.5	5.34
9-26-2	64	23.1	40.9	236	98	6.8	-	39.25	0.64	-	0.33	5.7	5.00
9-26-3	65.6	28.5	37.1	294	110	7.2	-	36.75	0.46	-	0.52	5.8	6.65

(3) Gage destroyed, Estimated from stage and current meter calibrations.
(4) Estimated from difference in flows from South Branch and North Branch at Paw Paw.

TABLE A 2

Daily Mean Discharges (cfs) at Upper Potomac River Stations.

September - October, 1956

Stream		North Branch Potomac River				Potomac River		Savage River		Georges Creek	New Creek	Wills Creek	Patterson Creek	South Branch Potomac River
Date	Location	Steyer, Md.	Kitzmiller, Md.	Luke, Md.	Pinto, Md.	Cumberland, Md.	Paw Paw, W. Va.	Barton, Md.	Bloomington, Md.	Franklin, Md.	Keyser, W.Va.	Cumberland, Md.	Headsville, W.Va.	Springfield, W.Va.
Sept.	10	25	82	195	249	259	808	16	122	24	5.6	102	16	244
	11	26	148	204	238	336	735	15	135	24	15	96	17	213
	12	29	190	377	392	417	721	15	121	24	22	92	72	267
	13	30	128	270	349	461	952	14	121	21	11	82	38	230
	14	22	108	219	279	359	815	11	121	18	8.0	74	26	217
	15	24	100	210	256	359	714	12	121	26	10	111	23	209
	16	44	152	253	304	568	928	22	121	41	14	220	33	221
	17	44	147	295	349	528	1070	18	121	28	11	165	31	213
	18	66	196	316	326	479	976	14	121	24	15	142	33	272
	19	37	124	274	363	485	976	11	121	20	11	123	27	317
	20	32	101	222	279	406	944	11	121	21	9.2	114	24	244
	21	30	90	210	252	354	778	10	121	18	8.0	101	20	230
	22	25	90	195	238	326	687	8.8	119	18	7.3	92	19	200
	23	25	106	207	224	308	635	8.2	119	17	6.8	86	18	192
	24	37	128	236	245	312	617	11	119	17	6.6	87	17	200
	25	24	128	260	259	336	648	8.2	119	15	6.3	82	16	213
	26	24	108	228	263	336	654	7.7	119	14	6.0	73	15	200
	27	31	120	232	256	326	674	7.7	119	18	10	71	18	205
	28	60	247	389	344	380	749	10	117	25	16	72	37	244
	29	46	183	365	447	510	890	8.8	117	18	11	71	37	272
	30	40	143	295	300	428	960	8.2	117	16	9.5	68	30	312
Oct.	1	32	124	260	300	364	882	7.2	117	15	8.4	61	25	302
	2	26	113	239	275	336	763	6.6	117	14	7.7	58	22	253
	3	24	110	228	263	321	687	6.2	117	14	7.3	57	21	226
	4	60	282	345	322	428	815	17	117	40	32	108	67	302
	5	64	478	580	668	762	1470	20	117	31	23	128	137	454
	6	60	374	490	545	691	1610	17	116	28	30	98	82	371
	7	190	692	923	879	929	1380	35	116	26	43	132	102	366
	8	106	464	734	940	1220	1800	34	116	29	29	138	76	322
	9	66	367	571	691	896	1560	27	116	24	20	125	55	292
	10	54	318	508	592	746	1300	21	116	21	16	114	42	272
	11	47	295	472	540	661	1150	17	116	19	14	101	37	244
	12	42	283	454	508	610	1050	14	116	18	13	92	32	221
	13	40	270	441	493	582	1000	13	116	17	12	87	30	213
	14	37	261	429	472	562	944	11	114	17	11	80	27	205
	15	34	206	385	457	541	905	10	116	16	10	76	25	196
	16	31	135	295	368	467	868	9.4	114	15	9.9	69	24	192
	17	31	124	253	300	390	756	8.8	114	15	9.2	67	23	184
	18	30	122	246	284	354	674	14	114	15	9.2	66	22	180
	19	28	124	242	275	345	648	13	112	14	8.8	65	21	176
	20	26	110	239	271	326	629	12	112	14	8.5	61	21	173
	21	28	103	213	259	326	617	8.8	112	14	8.0	60	21	173
	22	26	115	236	259	312	605	7.7	119	15	10	60	22	173
	23	68	190	312	292	350	617	11	112	20	14	66	26	180

Table A-3

Hourly Discharges at Times of Composite Sampling

Date,	Discharges (cfs)		Date,	Discharges (cfs)		Date,	Discharges (cfs)		Date,	Discharges (cfs)
Time	No. Br. at Luke	Savage R. at Bloom.	Time	No. Br. at Luke	Savage R. at Bloom.	Time	No. Br. at Luke	Savage R. at Bloom.	Time	No. Br. at Pinto
10.10. 6 P	494	116	10.14.12 P	417	114	10.16. 7 P	264	114	10.20. 12 P	271
7	494	"	10.15. 1 A	417	"	8	260	"	10.21. 1 A	271
8	490	"	2	417	"	9	260	"	2	271
9	490	"	3	417	"	10	260	"	3	271
10	486	"	4	417	"	11	260	"	4	271
11	486	"	5	413	"	12	260	"	5	271
12	486	"	6	413	"	10.17. 1 A	256	"	6	271
10.11. 1 A	481	"	7	413	"	2	256	"	7	267
2	481	"	8	413	"	3	256	"	8	267
3	481	"	9	413	"	4	256	"	9	263
4	481	"	10	413	"	5	256	"	10	263
5	476	"	11	409	"	6	256	"	11	259
6	476	"	12	409	"	7	253	"	12	256
7	476	"	1 P	401	"	8	253	"	1 P	256
8	476	"	2	385	"	9	253	"	2	256
9	472	"	3	373	"	10	253	"	3	252
10	472	"	4	358	"	11	253	"	4	252
11	472	"	5	351	"	12	253	"	5	252
12	472	"	6	340	"	1 P	253	"	6	252
1 P	468	"	7	337	"	2	253	"	7	252
2	468	"	8	334	"	3	253	"	8	252
3	468	"	9	334	"	4	250	"	9	252
4	468	"	10	330	"	5	250	"	10	252
5	468	"	11	330	"	6	250	"	11	252
6	463	"	12	330	"	7	250	"	12	252
7	463	"	10.16. 1 A	330	"	8	250	"	10.22. 1 A	252
8	463	"	2	330	"	9	250	"	2	252
9	463	"	3	326	"	10	250	"	3	252
10	463	"	4	326	"	11	250	"	4	252
11	458	"	5	326	"	12	250	"	5	252
12	458	"	6	326	"	10.18. 1 A	250	"	6	252
10.12. 1 A	458	"	7	323	"	2	250	"	7	252
2	458	"	8	320	"	3	250	"	8	252
3	458	"	9	316	"	4	250	"	9	252
4	458	"	10	306	"	5	250	"	10	252
5	458	"	11	298	"	6	246	"	11	252
6	458	116	12	292	"	7	246	"	12	252
			1 P	284	"	8	246	"		
			2	278	"	9	246	"		
			3	274	"	10	246	"		
			4	270	"	11	246	"		
			5	267	"	12 A	246	114		
			6	264	114					

TABLE A-4

pH AND ACIDITY ON THE NORTH BRANCH ABOVE LUKE, BELOW CONFLUENCE OF THE SAVAGE RIVER.*

			JAN.		FEB.		MAR.		APR.		MAY		JUNE		JULY		AUG.		SEPT.		OCT.		NOV.		DEC.
1949	Day		12		9		9	6	20	4	18	1	15	6	20	3	17	7	21	5	19		16		14
	pH		4.5		4.5		4.5	4.9	4.4	4.1	4.0	4.0	3.5	3.9	4.7	3.7	3.6	3.7	3.6	3.6	3.8		4.6		5.1
	Tot.Acid.		7.5		8.0		9.5	9.0	-	18	18	17.0	50	16	8.0	36.0	35.0	37.0	54.0	55.0	30.0		13.0		6.0
	Tot.Alk.		-		-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-		-
	Discharge		1015		1311		883	820	605	256	206	258	86	266	538	119	174	133	98	76	111		308		1306
	MB		796		976		640	568	475	190	156	204	69	218	430	94	154	111	87	66	90		262		846
	SR		219		335		243	252	130	66	50	54	17	48	108	25	20	22	11	10	21		46		450
1950	Day		11		15		15	5	19	3	17	7	21	5	19	2	16	6	20	4	18		15		13
	pH		4.8		5.3		6.0	4.7	4.4	5.2	6.2	5.1	4.9	4.2	4.5	4.6	3.7	4.0	5.0	5.1	5.4		6.4		5.9
	Tot.Acid.		11.0		12.0		3.5	-	13.0	2.0	-	4.5	6.0	19.0	11.0	12.0	30.0	13.0	9.0	9.0	5.0		8.0		3.0
	Tot.Alk.		-		-		-	-	-	4.0	7.0	-	-	-	-	-	-	-	-	-	-		-		-
	Discharge		1164		1885		1840	886	377	2335	1294	457	461	140	180	161	60	73	90	121	126		354		1170
	MB		868		1200		1340	689	292	1710	905	376	410	120	155	128	52	50	64	90	100		172		805
	SR		276		685		500	197	85	625	389	81	51	20	25	33	7.6	23	26	31	26		182		365
1951	Day		20		20		14	4	18	2	16	9	23	5	18	1	15	5	19	3	17	7	21	5	19
	pH		5.9		4.9		4.9	4.5	4.4	4.9	5.2	3.5	4.0	3.8	3.2	3.3	3.2	3.1	3.2	3.2	3.2	3.7	3.5	3.7	3.7
	Tot.Acid.		-		-		-	-	-	-	-	-	-	-	-	-	-	-	82	88	61	57	72	54	30
	Tot.Alk.		-		-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Discharge		2140		1380		914	1600	1290	1290	875	250	881	295	184	65	57	54	59	43	43	74	58	278	300
	MB		1756		935		533	1184	870	917	528	195	721	236	183	64	49	46	32	35	32	66	50	268	291
	SR		384		445		381	416	420	373	347	55	160	59	1.0	1.2	8.1	8.1	27	8.1	11	8.4	8.4	9.9	9.2
1952	Day	2	16	6	20	5	19	2	16	7	12	4	18	2	16	6	20							3	17
	pH	5.9	4.0	6.2	4.3	3.7	4.1	3.9	4.7	6.0	6.7	4.4	3.7	3.7	3.8	5.1	3.7	-------	-------	No Data	-------	-------	-------	6.1	5.6
	Tot.Acid.	12	19	-	4.6	21	17.8	7.0	-	-	-	11.4	14.5	8.2	28.2	-	38.7							-	17.0
					21.6		1.8					0.9					15.4								
	Tot.Alk.	-	-	11	-	-	-	-	1.3	5.5	7.0	-	-	-	-	4.5	-							10.5	
	Discharge	3450	725	1660	431	484	1160	563	1300	1640	1010	300	146	106	84	78	81							155	352
	MB	3363	714	1174	365	475	1147	551	1131	1156	798	226	79	52	41	30	52							57	257
	SR	87	11	486	66	8.8	13	12	169	484	212	74	67	54	43	48	29							98	95
1953	Day	7	21	6	18	4	18	1		6	20	3	17	1	15	3	19	2	16	7	21	4	18	5	19
	pH	4.9	6.3	4.3	6.2	4.1	4.3	4.4		4.4	5.1	5.9	3.8	3.6	4.3	3.8	3.9	4.7	4.3	6.9	3.9	3.9	4.7	4.3	3.9
	Tot.Acid.	-	-	-	-	18.6	11.4	12.3		-	-	-	13.2	22.0	-	8.0	8.0	-	-	-	38	33.5	-	-	27.0
						3.1	1.7	8.8													7.5	6.0			6.0
	Tot.Alk.	4.3	6.0	3.5	6.0	-	-	-		2.2	3.5	5.0	-	-	0	-	-	3.0	0	17.0		-	2.5	0	-
	Discharge	146	2167	815	1162	1612	1310	1039		984	1040	459	102	88	91	96	95	95	95	91	93	91	91	91	
	MB	52	1108	720	697	1514	1211	929		929	855	298	71	72.5	25	28	43	21	20	8	33	40	34	51	
	SR	94	1059	95	465	98	99	110		55	185	161	31	15.5	66	68	52	64	75	83	60	51	57	40	
1954	Day	6	20	3	17	3	17	7	21	5	19	2	16	7	21	4	18	1	15	6	20	3	17	1	15
	pH	3.6	4.1	5.0	4.0	6.5	4.5	3.7	3.9	3.7	3.9	3.9	5.1	3.5	3.6	3.7	4.1	5.1	3.7	3.9	6.5	5.0	4.7	6.3	4.5
	Tot.Acid.	48.5	21.0	-	17.0	-	-	25.0	18.5	22.5	19.0	18.0	-	43.5	43.5	29.5	12.5	-	30.0	22.5	-	-	-	-	-
		14.5	4.5		4.0			9.5	5.5	9.0	7.0	10.0		16.5	26.0	11.5	2.5		10.0	6.0					
	Tot.Alk.	-	-	3.0	-	5.5	0	-	-	-	-	-	2.0	-	-	-	-	2.5	-	-	5.0	2.0	2.0	7.0	0.5
	Discharge	99	484	291	612	3180	1060	462	609	397	426	566	598	102	181	370	667	454	141	233	1350	566	391	1540	806
	MB	88	413	208	604	1370	976	451	598	385	414	490	457	85	169	312	638	350	78	136	1074	469	296	996	719
	SR	11	71	83	8.5	1810	84	10.7	11.2	11.8	12.1	76	141	16.7	12.1	58	29	104	43	97	276	97	95	544	87
1955	Day	5	19	2	16	2	16	6	20	4	18	1	15	20	3	17	31	14	21	[illegible]	19	2	16	7	21
	pH	5.4	4.1	4.1	4.8	6.1	4.3	4.0	3.9	3.9	4.0	3.7	4.4	3.7	4.9	4.3	5.0	5.8	4.7	[illegible]	5.0	5.1	4.2	5.2	5.8
	Tot.Acid.	-	20.0	24.5	-	-	14.5	22.0	18.0	20.0	15.5	24.5	15.0	20.0	-	-	-	-	-	-	-	-	-	-	-
			4.0	5.5										2.0											
	Tot.Alk.	2.5	-	-	0.5	3.0	-	-	-	-	-	-	-	-	1.0	3.0	1.0	3.5	0.5	3.5	1.5	1.5	3.5	1.5	3.0
	Discharge	1710	428	405	719	3490	984	321	349	426	479	203	1170	121	104	853	347	186	288	110	124	104	219	257	153
	MB	1214	345	364	668	2480	899	310	337	412	404	156	960	89	39	152	245	83	206	37	55	51	210	210	67
	SR	496	83	41	51	1010	85	11	12	14	75	47	210	32	65	701	102	103	82	73	69	53	9.1	47	86

* Data obtained by the West Virginia Pulp and Paper Company.

TABLE A-5

Populations by Counties and Residence Categories
(1960 - 2010)

County	Name	% in Basin	Total	Farm	Non-Farm Rural Residential	Non-Farm Small Town	Non-Farm Urban
			1960				
Grant	W.Va.	50	4,100	1,650	1,050	300	1,100
Garrett	Md.	40	8,080	2,320	3,400	1,560	800
Mineral	W.Va.	100	22,500	2,900	7,900	400	11,300
Allegany	Md.	100	83,800	3,800	26,000	2,000	52,000
Bedford	Pa.	35*	7,100	2,030	2,980	1,360	700
Somerset	Pa.	25*	5,050	1,450	2,120	980	500
Totals			130,630	14,150	43,450	6,600	66,400
			1985				
Grant	W.Va.	50	6,350	1,550	2,100	500	2,200
Garrett	Md.	40	10,730	1,720	5,050	2,320	1,640
Mineral	W.Va.	100	33,800	2,500	12,200	600	18,500
Allegany	Md.	100	119,400	2,900	37,300	2,300	76,900
Bedford	Pa.	35*	9,360	1,500	4,400	2,030	1,430
Somerset	Pa.	25*	6,730	1,100	3,150	1,450	1,030
Totals			186,370	11,270	64,200	9,200	101,700
			2010				
Grant	W.Va.	50	9,050	1,300	3,500	550	3,700
Garrett	Md.	40	14,500	1,240	6,900	2,920	3,440
Mineral	W.Va.	100	50,500	2,100	18,700	1,000	28,700
Allegany	Md.	100	172,100	2,600	47,600	3,400	118,500
Bedford	Pa.	35*	12,700	1,080	6,100	2,550	3,000
Somerset	Pa.	25*	9,170	780	4,400	1,830	2,160
Totals			268,020	9,100	87,200	12,250	159,500

* Estimated as equivalent to portion of Garrett County located outside of basin.

Note: Source of Basic Data - OBE

TABLE A-6

Population Sub-division Breakdown

Sub-Basin and County	% County Population	Subdivision Numbers Water Supply & Pollution Abatement
North Branch		
Grant	50	1
Garrett	40	2
Allegany	5	
Mineral	30	
Allegany	70	3
Mineral	60	
Georges Creek		
Allegany	15	4
Wills Creek		
Bed Land	35*	5
Somerset	25*	
Allegany	10	
Patterson Creek		
Mineral	10	6

* Estimated as equivalent to Portion of Garrett County located outside of basin (OBE).

TABLE A-7

Subdivision Populations Served by Municipal
Water Supply Systems
(1960 - 2010)

Sub-Basin	Subdivision Number	Municipal Populations 1960	1985	2010
North Branch	1			
Rural Residential		260	1,050	2,620
Urban		1,100	2,200	3,700
Total		1,360	3,250	6,320
North Branch	2			
Rural Residential		1,760	5,300	11,180
Urban		6,780	11,040	18,270
Total		8,540	16,340	29,450
North Branch	3			
Rural Residential		5,740	16,700	33,400
Urban		43,180	64,900	100,750
Total		48,920	81,600	134,150
Georges Creek	4			
Rural Residential		980	2,800	5,370
Urban		7,800	11,560	17,800
Total		8,780	14,360	23,170
Wills Creek	5			
Rural Residential		1,920	5,640	11,450
Urban		6,400	10,150	17,010
Total		8,320	15,790	28,460
Patterson Creek	6			
Rural Residential		200	610	1,400
Urban		1,130	1,850	2,970
Total		1,330	2,460	4,370

Note: 1. Rural residential taken as 25%, 50% and 75% of totals in each subdivision for 1960, 1935 and 2010, respectively.

2. No small towns included.

TABLE A-8

Per Capita Daily Municipal Water
Requirements by Subdivisions
(1960 - 2010)

Sub-Basin	Subdivision Number	Per Capita Daily Gallons		
		1960	1985	2010
North Branch	1			
Average		80	118	155
Maximum		120	158	195
North Branch	2			
Average		80	118	155
Maximum		120	158	195
North Branch	3			
Average		150	185	225
Maximum		225	260	300
Georges Creek	4			
Average		122	163	213
Maximum		183	224	274
Wills Creek	5			
Average		75	103	131
Maximum		112	141	169
Patterson Creek	6			
Average		125	172	219
Maximum		187	234	281

TABLE A-9

Municipal and Industrial
Water Requirements by Subdivisions
(1960 - 2010)

Sub-Basin	Subdivision Number	Million Gallons Per Day		
		1960	1985	2010
North Branch	1			
Municipal				
Average		0.11	0.38	0.98
Maximum		0.16	0.51	1.23
North Branch	2			
Municipal				
Average		0.7	1.9	4.6
Maximum		1.0	2.6	5.7
Industrial				
Process		21	42	63
Cooling		51	102	153
North Branch	3			
Municipal				
Average		7.3	15.1	30.2
Maximum		11.0	21.2	40.2
Industrial				
Processing*		6.0	9.3	11.6
Cooling		37	60	83
Steam Electric**		40	202	365
Georges Creek	4			
Municipal				
Average		1.1	2.3	4.9
Maximum		1.6	3.2	6.3
Wills Creek	5			
Municipal				
Average		0.6	1.6	3.7
Maximum		0.9	2.2	4.8
Patterson Creek	6			
Municipal				
Average		0.17	0.42	0.96
Maximum		0.25	0.58	1.2

* Portion of total from Cumberland Supply as follows:
1960-3.5MGD; 1985-5.4MGD; 2010-6.8MGD. Remaining taken from North Branch in each case.

** Additional 250,000KW - 1985 and 500,000 KW - 2010

PART V

INVESTIGATION OF WATER USES, POLLUTION SOURCES, WATER QUALITY, AND WATER REQUIREMENTS FOR WATER SUPPLY AND POLLUTION ABATEMENT IN THE SHENANDOAH RIVER BASIN

ACKNOWLEDGMENTS

To develop a report of this kind requires considerable assistance and cooperation from many factions located in or having jurisdiction over matters relative to the study region.

The utmost cooperation in supplying necessary information and data was extended by State and interstate agencies, and municipal and industrial authorities in Virginia and West Virginia.

Regional information and hydrological data were provided through the cooperation of the U. S. Geological Survey and the Corps of Engineers, U. S. Army. The Office of Business Economics, U. S. Department of Commerce, provided invaluable data on future populations and economic development to be expected in the study region.

Special acknowledgment is made of the assistance given the U. S. Public Health Service by the city of Harrisonburg, Virginia, in providing space and facilities for operation of the mobile laboratory during the 1960 field survey.

INTRODUCTION

This report presents the results of an investigation of water uses, waste sources, and stream water quality in the Shenandoah River Basin and includes an evaluation of present and future water requirements for water supply and pollution abatement purposes in this region. The study was made at the request of the U. S. Army Engineer District, Washington, Corps of Engineers, to aid in the development of a comprehensive water resources plan for the Potomac River Basin. The report supplements a report prepared by the Public Health Service dated December 1959 on surface water quality in the upper Potomac Basin.

Authority for the Shenandoah Basin investigation was granted by the Corps of Engineers in a letter dated March 8, 1960, accepting and approving the plan of study as previously outlined by the Public Health Service in correspondence dated December 3, 1957, and as amended by the Memorandum of Agreement entered into on November 4, 1958, between the Army and the Department of Health, Education, and Welfare, covering assistance to be provided by the Public Health Service to the Corps of Engineers in the implementation of the water supply programs of the Corps of Engineers, authorized under the Water Supply Act of 1958 (Title III, P.L. 500, 85th Congress).

Contained within this report are compilations of water uses and sources, descriptions of the effects of wastes on receiving streams, recommended sanitary water quality objectives for stream water uses and protection of the aquatic environment, and discussions of factors involved and effects expected on water quality resulting from impoundment of stream waters at specific reservoir sites under investigation

by the Corps of Engineers. Water requirements for future supply and stream quality control in the Shenandoah Basin are given to the year 2010 as based on existing and projected population growth and industrial expansion expected.

The data on water uses and waste sources were provided by the Virginia State Water Control Board, the West Virginia Water Commission, and interviews with various municipal and industrial officials in Virginia and West Virginia.

Water quality data, other than those obtained during the Public Health Service field survey of September and October 1958 and May and June 1960, were provided by the Virginia State Water Control Board; both as directly collected and indirectly obtained through the cooperative sampling program between the Virginia State Water Control Board, Interstate Commission on the Potomac River Basin and three major Shenandoah Basin industries, namely: E. I. Dupont de Nemours Co., Inc.; Merck and Co., Inc; and American Viscose Corporation. Provisional stream flows were supplied by the U. S. Geological Survey. Population projections and economic evaluations for the determination of future industrial expansion were prepared by the Office of Business Economics, Department of Commerce. The Washington District, Corps of Engineers, provided invaluable assistance and guidance in identifying proposed reservoir sites, determining low flow frequencies and scheduling the progress of the studies.

SUMMARY

1. The Shenandoah River is the largest tributary of the Potomac River, with a drainage area of 3,054 square miles, or 20.8 per cent of the entire Potomac Basin and 26.2 per cent of the drainage area above Washington, D. C.

2. Approximately 200,000 persons reside in the Shenandoah River Basin constituting about one-fifth of the Potomac Basin population excluding the metropolitan Washington, D. C. area.

3. Incorporated communities population amounts to approximately 46 per cent of the total Shenandoah Basin population.

4. By the years 1985 and 2010 Shenandoah Basin population is expected to increase to 321,000 and 489,000, respectively.

5. By the years 1985 and 2010 urban population in the Shenandoah Basin is expected to constitute 52 and 57 per cent of the basin population, respectively.

6. The majority of urban population (62 per cent) is located in the "Three Rivers" area or the area comprising the extreme upper portion of the Shenandoah Basin.

7. Agricultural activities characterize the basic economy of the basin and industrial activities are on the increase in many areas.

8. The greatest industrial development has taken place in the "Three Rivers" area.

9. There are approximately 30 major water supplies serving about 128,000 persons and 12 individual supplies serving major industrial uses in the Shenandoah Basin.

10. The daily average water use for municipal, sanitary district, and institutional purposes in the basin is 13.5 million gallons of which about one-half is used in the "Three Rivers" area.

11. Daily average water use for industrial purposes is about 100 million gallons of which nearly 66 million gallons are used for steam-electric power production.

12. About 70 per cent of all water used in the "Three Rivers" area is obtained from surface water sources. The percentage of water obtained from surface sources within the South Fork, North Fork, and Main Stem Shenandoah River systems is 61.5, 100, and 94 per cent, respectively. All other water is obtained from wells and springs.

13. Surface and ground water is of limited supply in the "Three Rivers" and upper North Fork area of the Shenandoah River Basin. Most of the ground water requires treatment for hardness reduction prior to use for domestic purposes.

14. Approximately 102,000 persons are served by sewage collection systems in the Shenandoah River Basin. Depending on the size of communities and characteristics of waste receiving streams, the Virginia Water Control Board requires in some instances primary, and in other instances secondary treatment of wastes.

15. Sewage treatment facilities in the Shenandoah Basin remove about 55 per cent of all sewage BOD collected.

16. Industrial waste loads received in Shenandoah Basin streams, after all forms of treatment, amount to a total of 116,000 population equivalents of BOD which is 2.5 times greater than the domestic sewage BOD load.

17. The South Fork Shenandoah River and its headwater tributaries receive by far the greatest quantities and types of wastes of all other receiving streams in the basin.

18. Of the water quality parameters measured, the numbers of coliform organisms were found most frequently to exceed raw water quality objectives.

19. Waste discharges affecting significant dissolved oxygen depletions on the South Fork were most evident at sampling points downstream from Waynesboro, Staunton, Bridgewater, Harrisonburg, Elkton, and Front Royal, Virginia.

20. At times of lower flow than encountered during the May-June 1960 survey, significant dissolved oxygen depletions would occur on the North Fork downstream from Timberville, Mount Jackson, and Strasburg, Virginia.

21. According to sampling results at the mouth of the Shenandoah River in May-June 1960, an average BOD load of nearly one-half million population equivalents per day was entering the Potomac River from the Shenandoah River.

22. The average BOD in Shenandoah River water during May-June 1960 was over 40 per cent of that found in the Potomac River below the mouth of the Shenandoah River.

23. All composite samples analyzed for inorganic nitrogen contained concentrations in excess of the 0.3 parts per million reported to be associated with nuisance algal stimulation.

24. According to observed relationships between chemical oxygen demands and biochemical oxygen demands in samples collected at various points along the South Fork and Main Stem Shenandoah River, there is an indication that BOD inhibiting materials exist in the lower South Fork and Main Stem Shenandoah River.

25. Biological studies made during May-June 1960 showed that stream conditions were generally good at most points sampled as based on the types of bottom organisms and plant life observed. The South River downstream from Waynesboro, and Lewis Creek downstream from Staunton, Virginia, showed effects of excessive waste discharges. The only biological sampling station to reveal free-floating plankton was downstream from the power pool at Shenandoah, Virginia. The absence of Planktonic forms at most sampling stations, rather than being attributable to a lack of nutrient material or presence of toxic waste components, was believed to be a result of unsuitable climatic and physical conditions.

26. The suitability of water for water supply purposes was found to be essentially a function of the amount and character of wastes and rate of waste assimilation in the various streams.

27. Although not the only factor incident to nuisance algal blooms, the magnitude of inorganic nitrogen concentrations found could be expected to influence nuisance blooms of algae and perhaps nuisance weed growths in almost any possible stream impoundment area.

28. It is apparent that chlorination of sewage effluents for coliform organisms reduction would provide significant improvements and protection of downstream water users.

29. Considerable improvements in stream water quality can be expected upon completion and operation of the new treatment plants at Staunton and Bridgewater, and upon execution of the proposed plans for sewage treatment at New Market, Mt. Jackson, Edinburg, and Strasburg, Virginia.

30. Stream waters relative to the two proposed reservoir sites on the North River are of excellent quality for municipal and industrial water supply purposes.

31. Provided that used waters in the proposed Middle River Reservoir are not recycled to areas upstream, the once-through-detention of waters containing treatment plant effluents should yield water of suitable quality for supply purposes at a withdrawal point immediately above the dam.

32. In stabilizing upstream waters containing waste decomposition products from municipal and industrial sources, the waters released from the proposed South Fork Reservoir would be of improved quality for supply purposes downstream.

33. Stream water relative to the proposed reservoir site on the upper North Fork is of excellent quality for municipal and industrial purposes.

34. In stabilizing waters containing waste decomposition products from municipal and industrial sources upstream, the water released from the proposed Shenandoah River Reservoir would provide water of higher quality and greater minimum quantity than presently exists for water supply purposes at Washington, D. C.

35. Water supply requirements for 10 major Shenandoah Basin population subdivisions are given for the years 1960, 1985, and 2010, in Table 36, pages 378 - 380 of this report.

36. Flow requirements in combination with assumed waste treatment efficiencies for abatement of municipal and industrial waste pollution at 11 points of waste discharge are given for the years 1960, 1985, and 2010, in Table 40, pages 398, 399 of this report.

DESCRIPTION OF THE REGION

The Shenandoah River Basin is located entirely within the State of Virginia with the exception of 72 square miles (2.3 per cent of the total drainage area) near the mouth in West Virginia. It occupies the northwestern corner of Virginia and most of its westerly edge forms a portion of the State line between Virginia and West Virginia. The Shenandoah River, the largest tributary of the Potomac River, enters near Harpers Ferry, West Virginia, a distance of 171 river miles above the mouth of the Potomac River at Chesapeake Bay and 60 miles upstream from Washington, D. C. (see Figure 37).

From its upper to lower elevation, the basin is oriented lengthwise in a northeasterly position extending southwesterly from the Potomac River, a distance of approximately 120 miles. The major portion of the basin varies between 20 and 30 miles in width and lies between high mountain ranges.

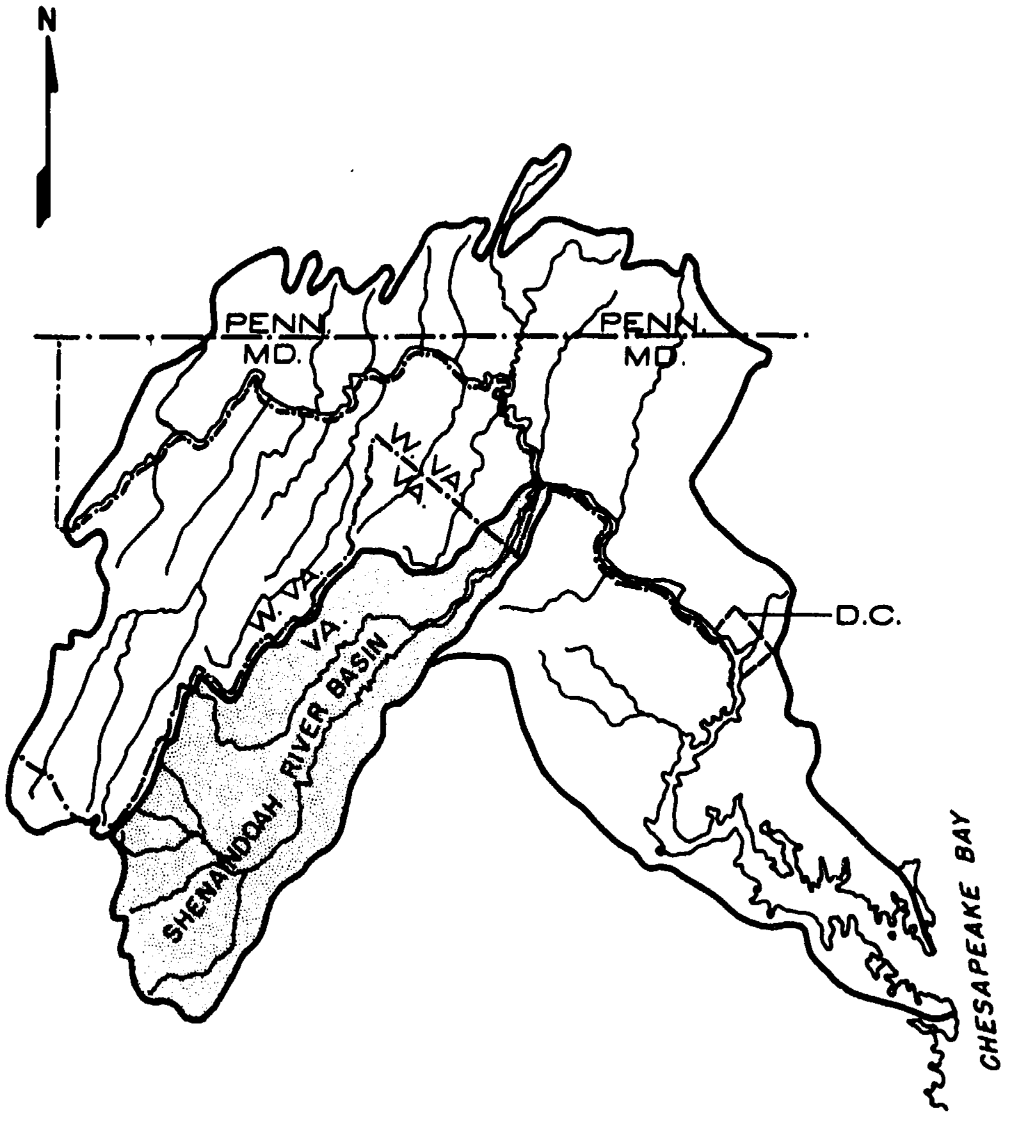
The shape and character of the Shenandoah Basin favors rapid runoff, with high stream discharges occurring for short periods of time and low discharges existing for sustained periods during drought seasons. Maximum discharges of more than 200,000 cubic feet per second and minimum discharges of less than 200 cubic feet per second have been recorded near the mouth of the Shenandoah River.

More than half of the population of the Shenandoah Basin resides on farms and in small rural communities. The largest municipality in the region is Staunton, Virginia, with over 20,000 persons. Next largest are Waynesboro and Harrisonburg, Virginia, each with a population over 10,000.

Farming and related industries such as poultry packing, meat packing, milk processing, canning, and tanning constitute the basic source of income to the region. Industrial activities other than farm produce processing have shown rapid growth and development in recent years. Products such as natural and synthetic textiles, plastics, electronics equipment, agricultural chemicals, fabricated steel products, and clothing are examples of the expanding diversity of manufactured goods in the region.

Portions of the Shenandoah Basin are considered to be among the Nation's most popular recreational areas. Many historic and scenic attractions exist in the basin, some of which are the Skyline Drive, Luray Caverns, and Natural Chimneys.

The basin contains abundant natural resources consisting of limestone, clay hard and soft woods, and granite. Many of these resources have been untouched, offering potentialities for large industrial development.



LOCATION OF THE SHENANDOAH RIVER BASIN
WITHIN THE POTOMAC RIVER BASIN

FIGURE 37

STUDY PROCEDURES

Initial studies began in 1958 when information on Shenandoah River Basin water supplies and waste sources were included in the report, Potomac River Basin Study, "Preliminary Compilation of Data on Water Uses in the Potomac River Basin," dated May 1958. Data included in the compilation were obtained from appropriate State and interstate agencies and from existing published data available at that time. Upon review of the initial compilation, various State agencies reported updated revisions which were incorporated in a revised issuance of data presented as "Parts I and II," Potomac River Basin Study, November 1958. Because many of the data necessary to the study were still unavailable, Public Health Service personnel conducted visits with various municipalities and industries to obtain the most recent information possible. These data, together with estimates where information was entirely lacking, were again revised and included in the water quality survey report, Report of the Potomac River Basin Study, "Part III," December 1959.

As appropriation limitations prevented study of the Virginia portion of the Shenandoah River Basin at the time of the 1958 field survey, Public Health Service visits with municipalities and industries were postponed until 1959 when Congressional approval of such studies was again granted. Some, but not all of these data on Shenandoah Basin water uses were obtained in time to be included in the "Part III" report mentioned above.

This report includes the most recent and accurate data possible on municipal and industrial water and wastes in the Shenandoah Basin as obtained from industrial visits in September 1959 and municipal visits made in April, May, and June 1960. Most of the water quality data presented were obtained during the Public Health Service survey of May and June 1960 and from sampling records supplied by the Virginia State Water Control Board and Interstate Commission on the Potomac River Basin in cooperation with E. I. Dupont de Nemours Company, Inc.; Merck and Company, Inc.; and American Viscose Corporation.

Future water needs, waste effects on water quality, and the possible uses that could be made of water storage projects for water supply and pollution abatement in the various areas considered in this report are based on sub-area population and employment figures developed by the Corps of Engineers in consultation with the Office of Business Economics and Public Health Service as taken from the regional economic evaluation prepared by the Office of Business Economics. Future water requirements for municipal and industrial uses given in the report represent Public Health Service per capita rates and industrial water use estimates as applied to projected population and employment data estimated for specific local areas. Future water quality

control aspects reflect waste effects on water quality resulting from the particular water uses and where applicable reflect the anticipated waste treatment measures that will be applied or required prior to returning the used water to the stream.

To determine the possible extent to which various proposed reservoirs and associated low flow increases could be utilized for water supply and pollution abatement, requirements for these purposes for areas adjacent and downstream from these projects are estimated for the years 1960, 1985, and 2010. These data are then plotted against design minimum stream flows for the purpose of estimating quantities and times at which stored water could be utilized. Requirements for municipal and/or sanitary district water supply are combined by areas (municipal - district) to indicate demands by entire metropolitan population regardless of the water distribution authority or authorities. Such areas are considered to contain urban, rural residential, and in some cases small town population plus related commercial, institutional, and small industrial water users.

The criteria and rationale used to estimate future municipal - district and self-supplied industrial water supply requirements and waste quantities and effects are given in later sections of the report.

The design minimum stream flow data associated with area water supply and pollution abatement requirement evaluations shown in the report were taken from data prepared by the Corps of Engineers in consultation with the Public Health Service. Many of these data represent computation involving flow data regressions and drainage area adjustment to various water intake points or waste receiving reaches, based on minimum flow of record at key gaging stations on which sufficient historical data are available. The dependable unregulated stream flows used for water supply evaluations throughout the Potomac Basin are essentially the minimum flow of record which occurred in 1930 and are referred to as the 1-day, 30 year stream flows.

The minimum average 7-day, 10 year stream flow used for pollution abatement flow evaluations is arbitrarily applied to all unregulated streams in the Upper Potomac Basin in order to maintain consistency in determining needs for low flow augmentation.

The water sampling program conducted by the Public Health Service in May and June 1960 involved 37 sampling stations throughout the Shenandoah Basin in the States of Virginia and West Virginia and included several additional stations on the Potomac River in Maryland. For sampling purposes, the area was divided into four sections in order that the streams in each could be sampled conveniently and the samples returned to the Public Health Service mobile laboratory located at the Harrisonburg, Virginia, sewage treatment plant within six to eight hours from the time the first sample was collected each

day. Seven grab samples were collected at each of 35 sampling stations on different days of the week and times of day in order to measure extremes of variability. Eight hour composites made up of four samples collected every two hours were obtained three times during the survey at eight sampling points to further measure the extremes in daily variability of stream quality above and below important waste sources.

For sampling station identification purposes, each station was assigned a prefix letter corresponding to the particular stream name; that is, S - South Fork Shenandoah, N - North Fork Shenandoah, M - Main Stem Shenandoah, and P - Potomac River. Numbers following the prefix letters identify the sampling station within the particular stream section. Sampling station locations with identification letters and numbers are shown in Figure 38 and corresponding descriptions of the locations are shown in Table 20.

Each grab sample collected was analyzed in the mobile laboratory for dissolved oxygen, five-day 20°C. BOD (BOD_5), numbers of coliform organisms, color, phenolphthalein and total alkalinity, and pH (hydrogen-ion concentration). Water temperatures, stream gage readings, and weather conditions were recorded at the time of sampling. Composite samples were analyzed for daily BOD satisfaction in duplicated series of 1, 2, 3, 5, 7, and 9 days, and included an analysis of chemical oxygen demand, pH, phenolphthalein and total alkalinity, color, total and dissolved solids and Kjeldahl, nitrite and nitrate nitrogen. Individual samples making up the composite were analyzed for dissolved oxygen and numbers of coliform organisms. Where stream width and currents were such that horizontal mixing of wastes was uncertain, samples were collected at quarter points across the stream and composited to a single sample representing the total cross-section. Water temperatures, weather conditions, and stream gage readings were recorded during the composite sampling periods.

All perishable samples were chilled in ice chests prior to delivery to the laboratory. Laboratory analyses were performed in accordance with approved procedures outlined in Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, 10th Edition, except that the tentative method for counting coliform organisms by the membrane filter technique was used instead of the statistical tube test for most probable numbers of coliform organisms.

Following is a discussion of the use made of parameters analyzed in evaluating the sanitary quality of stream water.

TEMPERATURE

The temperature of water controls the oxygen solubility and thus the saturation level of dissolved oxygen in the stream. Biological activity and waste degradation processes are also affected by water

temperature. Since dissolved oxygen saturation levels reduce and deoxygenation rates increase with increases in temperature, this parameter is important in computing critical low flow effects that may be expected in stream section receiving oxygen demanding wastes.

DISSOLVED OXYGEN (D.O.)

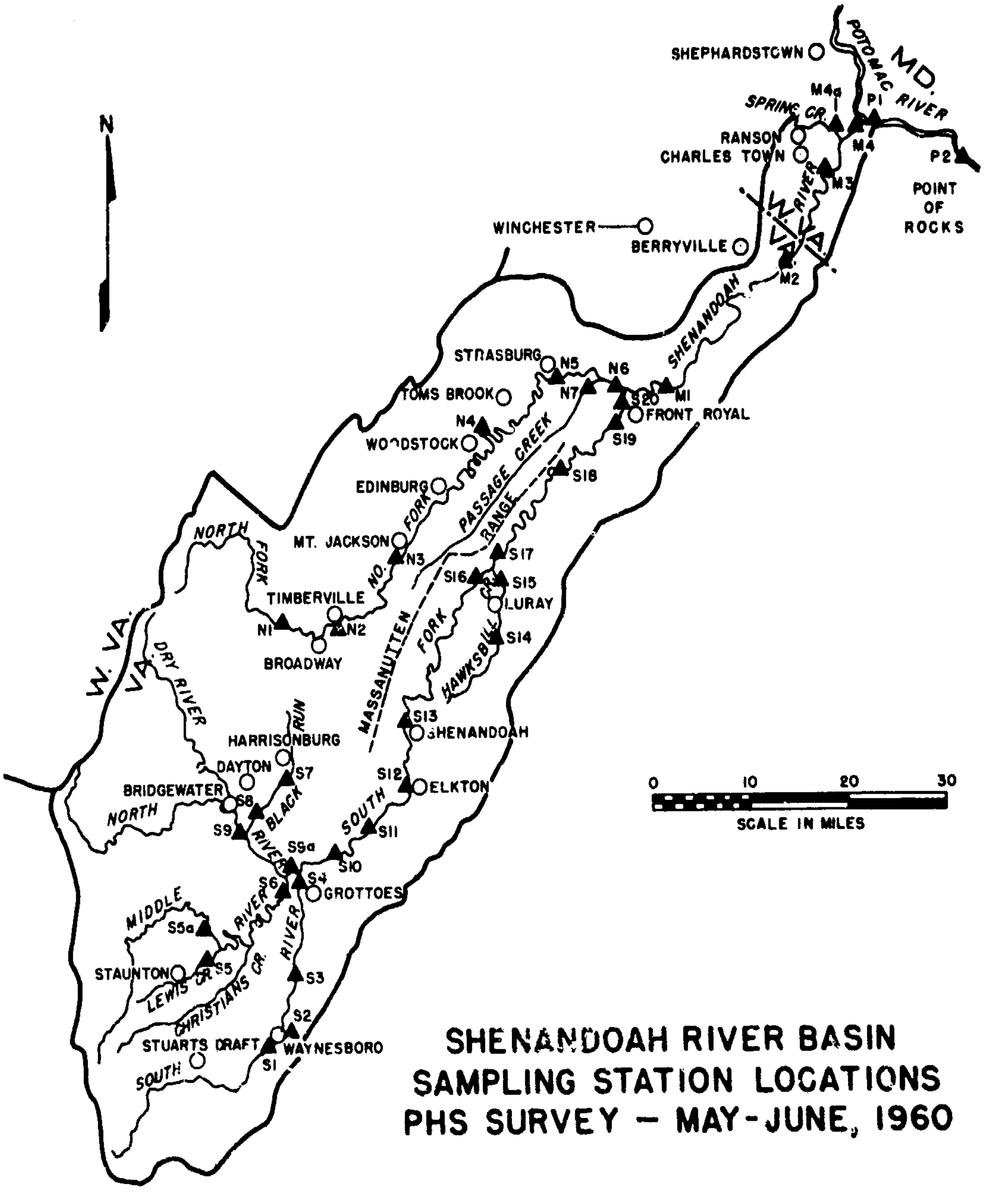
The amount of oxygen that may be dissolved in water is limited by temperature and amounts of dissolved and colloidal material present. At sea level and temperature of 20°C. the saturation value of dissolved oxygen in pure water is 9.17 ppm. Atmospheric oxygen provides the major source of dissolved oxygen replenishment in water. Under certain conditions, atmospheric oxygenation may be supplemented by photosynthetic oxygenation from aquatic plant life resulting in supersaturation of dissolved oxygen. Dissolved oxygen must be present to support fish and aquatic life and prevent anaerobic putrefaction of stream waters. The minimum permissible concentration is dependent on the quality of water desired. Dissolved oxygen values below the saturation level are an indication of the presence of organic pollution from sources such as sewage and organic industrial waste, agricultural land runoff, forest and natural land runoff or oxygen demands exerted during respiration, and die-off of over-abundant blooms of algae and aquatic plant life. Because dissolved oxygen levels provide a gross appraisal of many factors taking place in stream water and because it is easily measured and can be controlled by removal of oxygen demanding materials from man-made wastes, universal use has been made of this parameter for waste treatment plant design, stream standards for protection of aquatic life, abatement criteria for determining low flow augmentation requirements, and evaluation of stream assimilative capacity in connection with permissible stream loadings.

BIOCHEMICAL OXYGEN DEMAND (BOD)

The biochemical oxygen demand of sewage, sewage plant effluents, industrial wastes, or polluted waters is a measure of the oxygen (in parts per million) required to stabilize decomposable organic matter by aerobic bacterial action. Complete stabilization requires more than 100 days at 20°C., but such long periods of incubation are impractical. Consequently, a much shorter period of incubation is used. Incubation for 5 days at 20°C. (BOD_5) is recommended as the standard procedure and this procedure was followed during the field survey. Measurements of daily BOD in time series (long term BOD) when plotted produce a logarithmic curve from which deoxygenation velocity constants can be computed. Use of these values is made in computing critical dissolved oxygen concentrations to be expected at various stream flows and waste loadings.

COLIFORM GROUP ORGANISMS

This determination is an indicator of sewage pollution, since these organisms are normally present only in the intestines of warm-blooded animals and are discharged in vast numbers in human feces.



SHENANDOAH RIVER BASIN
SAMPLING STATION LOCATIONS
PHS SURVEY – MAY-JUNE, 1960

FIGURE 38

Table 20

Shenandoah River Survey
Sampling Station Descriptions

Location in Potomac Basin	Station No.	Description of Location
Shenandoah River		
South Fork		
South River	S-1	Bridge on Chestnut Ave., Waynesboro, Virginia (gaging station)
	S-2	Bridge on Broad St., Waynesboro, Va.
	S-3	Bridge on Co. Rd. 611 off US 340 north of Waynesboro, Va. (Coiners Mill)
	S-4	Bridge on Rockingham Co. 865 at Port Republic, Virginia
Middle River	S-5a	Right bank on Augusta Co. 681, NW of Verona, Va., 0.3 mile off of US 11
Lewis Creek	S-5	Bridge at Augusta Co. Junction 792 and 790, east of Staunton, Va.
Middle River	S-6	Bridge of Va. 256, west of Grottoes, Va., at Mt. Meridian, Va. (gaging station)
North River		
Blacks Run	S-7	Bridge on Rockingham Co. 726 off of US 11, south of Harrisonburg, Va.
	S-8	Bridge on Augusta Co. 867 east of Mt. Crawford, Virginia
North River	S-9	Bridge on US 11, south of Mt. Crawford, Va. (upstream from Burketown gaging station)

Table 20
(Continued)

Shenandoah River Survey
Sampling Station Descriptions

Location in Potomac Basin	Station No.	Description of Location
Shenandoah River		
South Fork		
North River	S-9a	Bridge on Rockingham Co. 865 at Port Republic, Virginia
South Fork	S-10	Bridge on Rockingham Co. 659, off of US 340, north of Grottoes, Va. (downstream from Lynwood gaging sta.)
	S-11	Bridge on Rockingham Co. 649, off of US 340, east of McGaheysville, Va.
	S-12	Bridge on US 33 west of Elkton, Va.
	S-13	Bridge on Page Co. 602, west of Shenandoah, Va.
Hawksbill Creek	S-14	Bridge on Page Co. 642, off of US 340, south of Luray, Va.
	S-15	Bridge on Page Co. 648, northwest of Luray, Va. (low water bridge)
South Fork	S-16	Bridge on Page Co. 678, northwest of Luray, Va. (low water bridge)
	S-17	Left bank at end of Page Co. 660, northwest of Luray, Va.
	S-18	Bridge on Warren Co. 613 west of Bentonville, Va. (low water bridge)
	S-19	Bridge on Warren Co. 619, Luray Ave., Front Royal, Va. (gaging station)

Table 20
(Continued)

Shenandoah River Survey
Sampling Station Descriptions

Location in Potomac Basin	Station No.	Description of Location
Shenandoah River		
South Fork	S-20	Bridge on US 340, 0.5 mile north of Front Royal, Va.
North Fork	N-1	Bridge on Virginia 259 near Cootes Store, Va. (gaging station)
	N-2	Bridge on Va. 42 at Timberville, Va.
	N-3	Bridge on Shenandoah Co. 767, east of Quicksburg, Va. off of US 11
	N-4	Bridge on Shenandoah Co. 663, northeast of Woodstock, Va. off of US 11 (low water bridge)
	N-5	Bridge on Va. 55, east of Strasburg, Va. (gaging station)
	N-6	Bridge on US 340, 0.75 mile north of Front Royal, Virginia
Passage Creek	N-7	Bridge on Virginia 55, 4 miles west of US 340
Shenandoah River (Main Stem)	M-1	Bridge on Warren Co. 624, west of Howelsville, Va., off of US 340 (low water bridge)
	M-2	Bridge on Virginia 7, east of Berryville, Va.
	M-3	Bridge on Virginia 9 at Bloomery, Va., (upstream from Millville, W. Va., gaging station)

Table 20
(Continued)

Shenandoah River Survey
Sampling Station Descriptions

Location in Potomac Basin	Station No.	Description of Location
Shenandoah River (Main Stem)	M-4	Bridge on US 340, east of Harpers Ferry, West Virginia
Spring Creek	M-4a	Bridge on West Virginia 27 at Millville, West Virginia
Potomac River	P-1	Bridge on US 340 at Knoxville, Md.
	P-2	Bridge on US 15, at Point of Rocks, Md.

Unpolluted streams contain very small numbers of coliform organisms; therefore, the presence of large numbers indicates sewage or fecal pollution. The numbers of coliform organisms shown in this report were determined by the membrane filter technique and are reported as the estimated number of organisms present per 100 ml of sample (Direct Membrane Filter Test). Compared with results by the statistical tube test (MPN), the direct count method produces lower values. Established stream quality criteria are based on MPN values. Therefore, results by the Direct Membrane Filter Test compared with stream quality criteria would lead to somewhat conservative conclusions.

CHEMICAL OXYGEN DEMAND

This is a measure of the oxygen consumed by chemical oxidation of carbon and hydrogen in organic matter contained in the sample. The test is used to determine the relative "strength" of wastes and in this instance to estimate by comparison with BOD the extent to which carbonaceous organic matter contained in the samples was oxidized by natural processes in the stream.

KJELDAHL NITROGEN

This determination includes a measurement of ammonia and organic nitrogen, but does not include nitrite and nitrate nitrogen. The test was used in this investigation as a means of determining the location of significant sources of nitrogenous material and by comparing relative concentrations with nitrite and nitrate nitrogen to determine the presence or absence of nitrifying bacteria depending on whether or not bacterial inhibiting toxicants were present at various points in the stream.

NITRITE NITROGEN

This constituent is an intermediate oxidation or reduction product which, if present, indicates the presence of nitrifying bacteria and an unstable condition produced in the presence of polluting substances. Special use is made of the determination in this investigation to qualitatively detect the presence or absence of biological or bacterial inhibiting toxic waste components based on nitrite concentrations relative to Kjeldahl nitrogen concentrations.

NITRATE NITROGEN

This constituent represents the most highly oxidized phase in the nitrogen cycle and is the final stage of biological oxidation. Trace quantities often occur in surface waters and excessive amounts (10 ppm or greater) are suspected of contributing to, or being associated with the illness known as infant methemoglobinemia. Waters containing concentrations of inorganic nitrogen in excess of 0.3 ppm and inorganic phosphorus in excess of 0.01 ppm can, under certain climatic

conditions, generate algal nuisance-forming blooms.[1] Use is made of the determination in this investigation to predict stream impoundment effects on water quality and to qualitatively detect the presence or absence of biological or bacterial inhibiting toxic waste components based on nitrate concentrations relative to Kjeldahl nitrogen concentrations.

pH (HYDROGEN-ION CONCENTRATION)

pH is defined as the negative logarithm of the hydrogen-ion concentration. The pH value indicates the relative acidity or alkalinity of water, with the neutral point at pH 7.0. Values lower than 7.0 indicate the presence of acid salts, and values higher than 7.0 indicate the presence of alkalies or alkaline earth salts.

ALKALINITY

The alkalinity of water, which may be defined as its capacity for neutralizing acid, is usually due to the presence of bicarbonate and carbonate ions. Total alkalinity is determined by titration with dilute sulfuric acid to an end point of pH 4.0. Phenolphthalein alkalinity or that produced by hydroxide, borate, silicate or phosphate ions is determined by titration with dilute acid to pH 8.3. Phenolphthalein alkalinity measurements made in this investigation were also used as an indirect indication of the relative abundance of algae as implied by photosynthetic utilization of carbon dioxide (hydroxide release) in the stream waters.

COLOR

The color of water is defined as that color due only to substances which are actually in solution and does not include color due to suspended matter. Certain industrial wastes such as textile dye wastes and tannery waste may persist in stream waters for many miles downstream. The platinum-cobalt method of measuring color is the standard method, and the unit of color is that produced by one milligram of platinum ion per liter. The test was used in this investigation to trace the persistence of color in streams receiving colored industrial wastes.

BIOLOGICAL SAMPLING

Sampling in rocky riffle areas for aquatic animals was accomplished by turning many rocks by hand and by use of a Surber square foot sampler. Sampling among aquatic vegetation was done with a BV

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[1] Lackey, J. B. and Sawyer, C. N., "Plankton Productivity of Certain Southeastern Wisconsin Lakes as Related to Fertilization," I. Surveys, Sewage Works Journal, 17:2, (1945).

dip net and the bottoms of shallow pools were sampled with an Eckman dredge. Plankton samples were collected by straining a known volume of stream water through a standard mesh plankton net and catching the concentrated material in a 15 ml vial. Descriptions of the sampling point and all other pertinent data were recorded at the time of sampling. The biological sampling station numbers and locations are given in Table 21.

PRESENTATION OF DATA

DESCRIPTION OF AREA INVESTIGATED

There are two major drainage systems within the Shenandoah Basin, namely: the North Fork and the South Fork systems. These systems converge in the lower portion of the basin to form the Main Stem of the Shenandoah River. The areas drained by the North and South Forks lie on opposite sides and to the south of the Massanutten Mountain Range. The South Fork (drainage area - 1,653 square miles) drains the larger of the two major areas in that the entire southern and most of the eastern section of the basin are drained by this system.

The sub-system of the South Fork which drains the southernmost portion of the basin is composed of the North, Middle, and South Rivers. The Middle River drains the middle and western portion of the sub-area (drainage area - 363 square miles); the North River drains the northwestern portion (drainage area - 441 square miles); and the South River drains the southeastern portion of the sub-area (drainage area - 272 square miles). The three rivers converge near Grottoes, Virginia, to form the upper reach of the South Fork. The area drained by the "Three Rivers" system is 65 per cent of the total South Fork drainage area.

The North Fork drains the area west of the Massanutten Mountain Range (drainage area - 1,036 square miles). The Main Stem of the Shenandoah River, in addition to carrying flow from the North and South Forks, drains the lower or northeastern portion of the basin (drainage area - 365 square miles), thus discharging drainage from a total area of 3,054 square miles to the Potomac River (see Figure 39).

The South and Middle Rivers each rise in rolling hill country at elevations of approximately 1,900 and 2,000 feet, respectively; and the North River rises in mountainous terrain at an elevation of about 4,500 feet. From its source southeast of Greenville, Virginia, the South River flows 48.5 miles northeasterly paralleling the Blue Ridge Mountains to Grottoes, Virginia. The Middle River, 62 miles in length, rises near Summerdean, Virginia, flowing north and northwest to Long Glade, then southeast to Verona, then northeast to the North River. For a distance of 51.5 miles from its source on Briery Branch near the West Virginia State line, the North River flows south, then east to Mt. Solon, then north to Sangerville, then east and southeast to the South River near Grottoes where the confluent streams form the upper reach of the South Fork Shenandoah River (see Figure 40).

Table 21

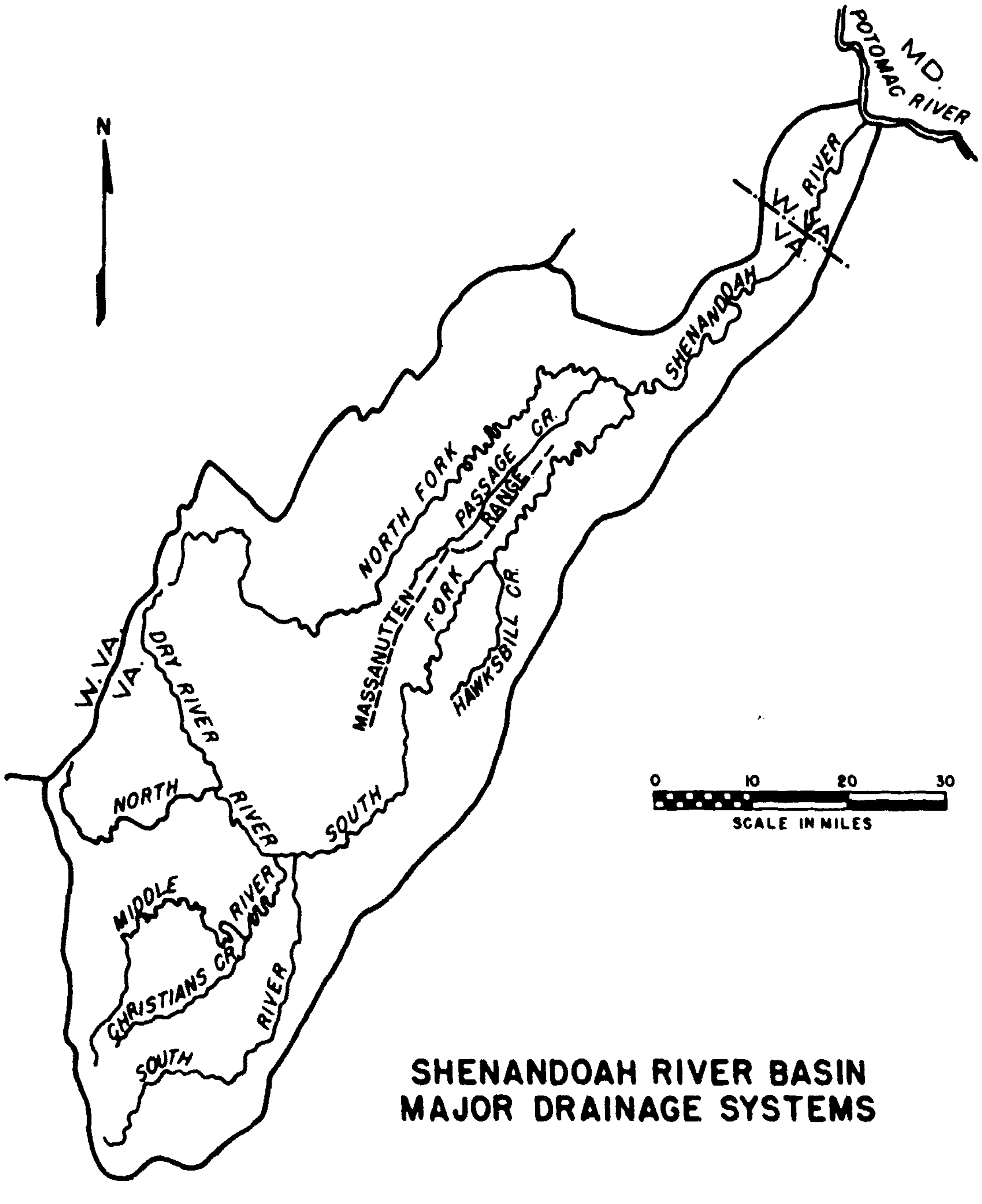
Biological Sampling Stations

Station No.	Location
S-1	South River - bridge on Chestnut Ave., Waynesboro, Va.
S-1a	South River - several hundred feet downstream from Chestnut Avenue bridge
S-1b	South River - 350-400 yards downstream from Chestnut Avenue bridge and 150-250 yards above the gate to the Du Pont Plant
S-2	South River - bridge on Broad St., Waynesboro, Va.
S-3	South River - 150-200 yards upstream from bridge on Co. Rd. 611 off of US 340 north of Waynesboro, Va. (Coiner's Mill)
S-4a	South River - 0.5 miles downstream from bridge on Rockingham Co. Rd. 865 at Port Republic, Va.
S-5	Lewis Creek - bridge at Augusta Co. junction 792 and 790 east of Staunton, Va.
S-11	South Fork - bridge on Rockingham Co. Rd. 649 off of US 340 east of McGaheysville, Va.
S-12a	South Fork - left bank of the river at the Elkton, Va. city dump
S-13a	South Fork - below the power dam tailrace located on Page Co. Rd. 602 west of Shenandoah, Va.
S-14a	Hawksbill Creek - 0.25 miles downstream from US 340 bridge south of Luray, Va.
S-15	Hawksbill Creek - low water bridge on Page Co. Rd. 648 northwest of Luray, Va.

Table 21
(Continued)

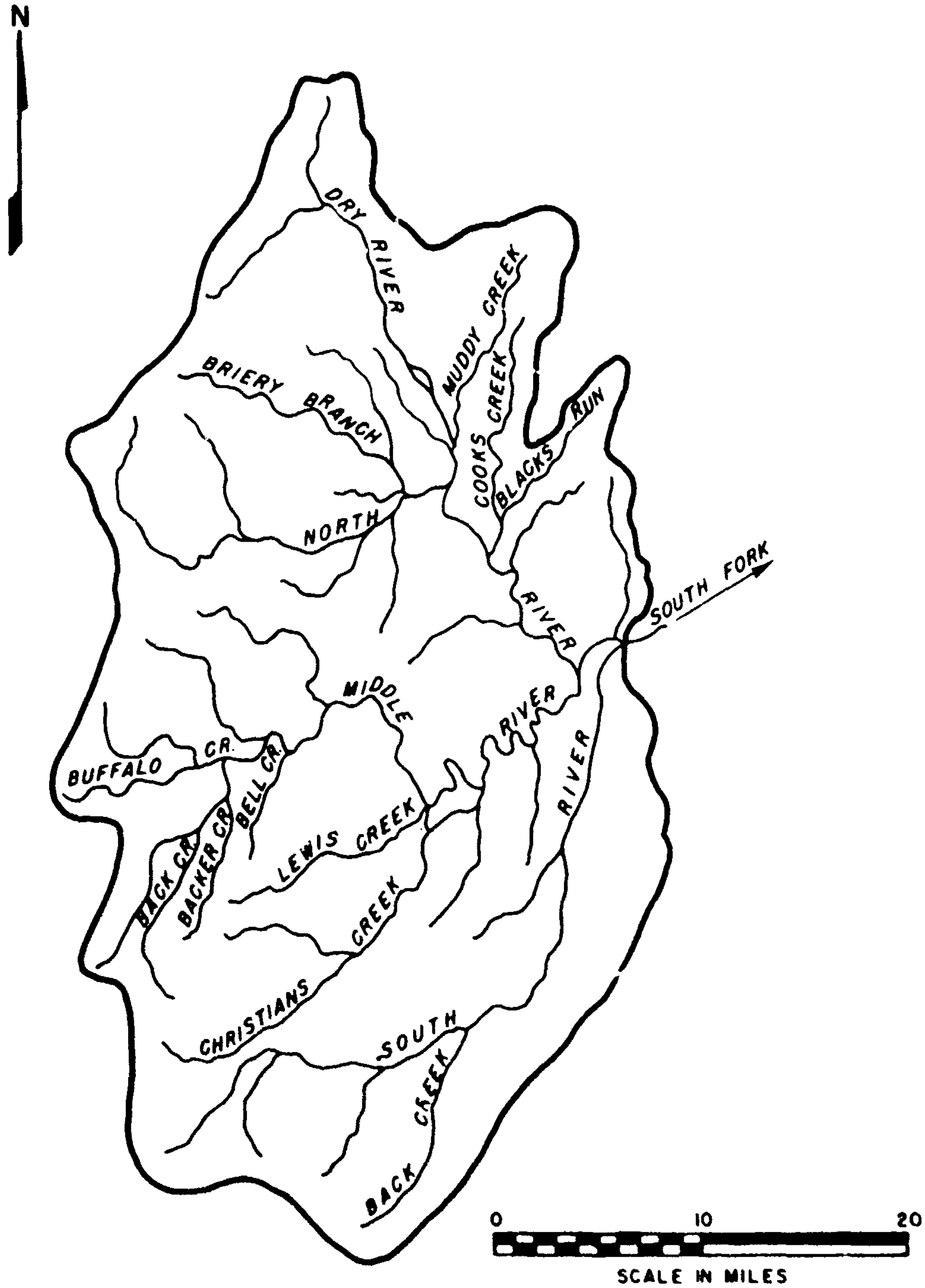
Biological Sampling Stations

Station No.	Location
S-16	South Fork of the Shenandoah River - low water bridge on Page Co. Rd. 678 northwest of Luray, Va. Upstream from the confluence of Hawksbill Creek with the South Fork of the Shenandoah River
S-18	South Fork of the Shenandoah River - low water bridge on Warren Co. Rd. 613 west of Bentonville
N-1	North Fork bridge on Rockingham Co. Rd. 612 near Cootes Store, Va.
N-2a	North Fork - 0.25 mile below the Virginia Rt. 42 bridge at Timberville, Va.
N-5	North Fork - bridge on Virginia Rt. 55 east of Strasburg, Va.
M-1	Main Stem of Shenandoah River - low water bridge on Warren Co. Rd. 624 downstream from Front Royal, Va.



SHENANDOAH RIVER BASIN
MAJOR DRAINAGE SYSTEMS

FIGURE 39



UPPER SHENANDOAH RIVER BASIN
THREE RIVERS AREA

FIGURE 40

From near Grottoes, Virginia, the South Fork traverses a torruous 101.5 mile course northeasterly to its confluence with the North Fork near Front Royal, Virginia.

The North Fork rises 6 miles west of Bergton, Virginia, at an elevation of about 1,400 feet flowing 115 miles to its confluence with the South Fork. From Bergton the North Fork flows southerly, turns easterly to Timberville, Virginia, and then northeasterly paralleling the Massanutten Mountain Range and South Fork lying to the east (see Figure 41). The lower sections of the North and South Forks each flow through wide valleys of open farm land and small wooded areas.

From its point of origin at the confluence of the North and South Forks near Front Royal, the Main Stem of Shenandoah River flows a winding 55 mile northeasterly course through a wide valley of fertile farm land to the Potomac River near Harpers Ferry (see Figure 42).

The 3,054 square mile area comprising the Shenandoah Basin constitutes 20.8 per cent of the entire Potomac Basin and 26.2 per cent of the drainage area above Washington, D. C. All but 72 square miles of the area lies within the borders of the State of Virginia comprising 7.3 per cent of the total State area. Included within the area is most of Augusta County; all of Rockingham, Page, Warren, and Shenandoah Counties; three-fourths of Clark County and one-third of Frederick County. The 72 square mile area not included in Virginia lies immediately upstream from the mouth of the Shenandoah River and constitutes the extreme northeastern corner of West Virginia. This area includes approximately one-half of Jefferson County, West Virginia.

All portions of Shenandoah Basin are accessible by improved highways, two of which are important interstate routes linking portions of North Carolina and Tennessee with points to the North in Maryland and Pennsylvania. The Chesapeake and Ohio Railroad crosses the upper basin; the Baltimore and Ohio Railroad crosses the lower. Norfolk and Western Railroad serves the eastern portion of the basin, and the Chesapeake Western Railroad serves the western portion connecting with points north, south, and east.

The Shenandoah River Basin contains nearly 150 communities, most of which are rural unincorporated farming centers having populations of less than 100-200 persons. There are 28 incorporated communities. In 1950 approximately 179,000 persons resided in the region, constituting 5.2 per cent of the State population of Virginia and 24 per cent of the population in the Potomac Basin above Washington, D. C. Estimates for 1957 reveal an increase in population to 193,500, attributable mainly to urban increases. Estimates for 1960 show a total of 198,500 persons or an increase of 11 per cent from 1950.

In 1950 the municipal or incorporated urban centers contained 76,750 persons or 43 per cent of the basin population. Estimates for 1960 indicate an increase in urban populations to 91,500, an increase of 19 per cent and amounting to 46 per cent of the estimated basin population.

The largest municipality in the basin is Staunton, Virginia (population 22,667). The next major communities in order of size are Waynesboro (population 15,519), Harrisonburg (population 11,890), and Front Royal (population estimate 9,000). The remaining 24 incorporated communities contain population of 4,500 or less. A list of communities with population is given in Table 22.

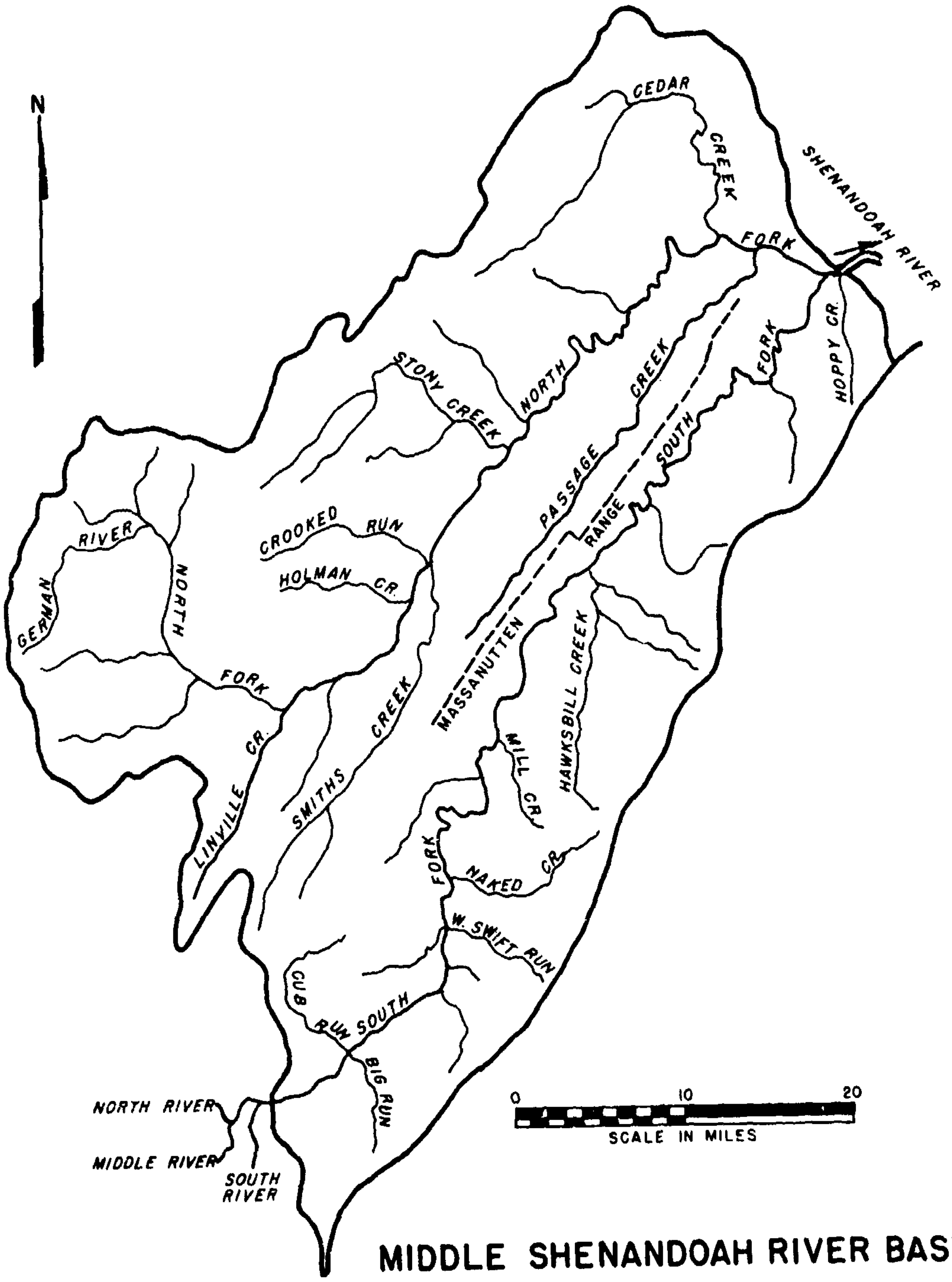
The majority of urban population shown in Table 22 (62 per cent) are located in the "Three Rivers" area at the extreme upper portion of the Shenandoah Basin (see Figure 43). All other urban population are located at various points in the middle and lower portions of the basin as shown in Figures 44 and 45.

Extensive agricultural activities characterize the majority of land uses in the Shenandoah Valley. Poultry, stock grazing, hay, grain, and apple growing constitute the main agricultural enterprises. Significant industrial development has been in progress in several major areas for the past 30 years. Original industries have expanded to many times the original size and within the past 10 years many new industries have located in the valley. The greatest industrial growth has taken place in the "Three Rivers" area at the upper or south end of the basin. The major products associated with important development areas are shown in Table 23.

All communities in the Shenandoah Basin provide some form of agricultural service. Communities that provide agricultural supplies and services exclusively have shown very little and in many cases no community progress for many years. The growing communities are mainly those supported by large industries or by a diversity of manufactured or processed products.

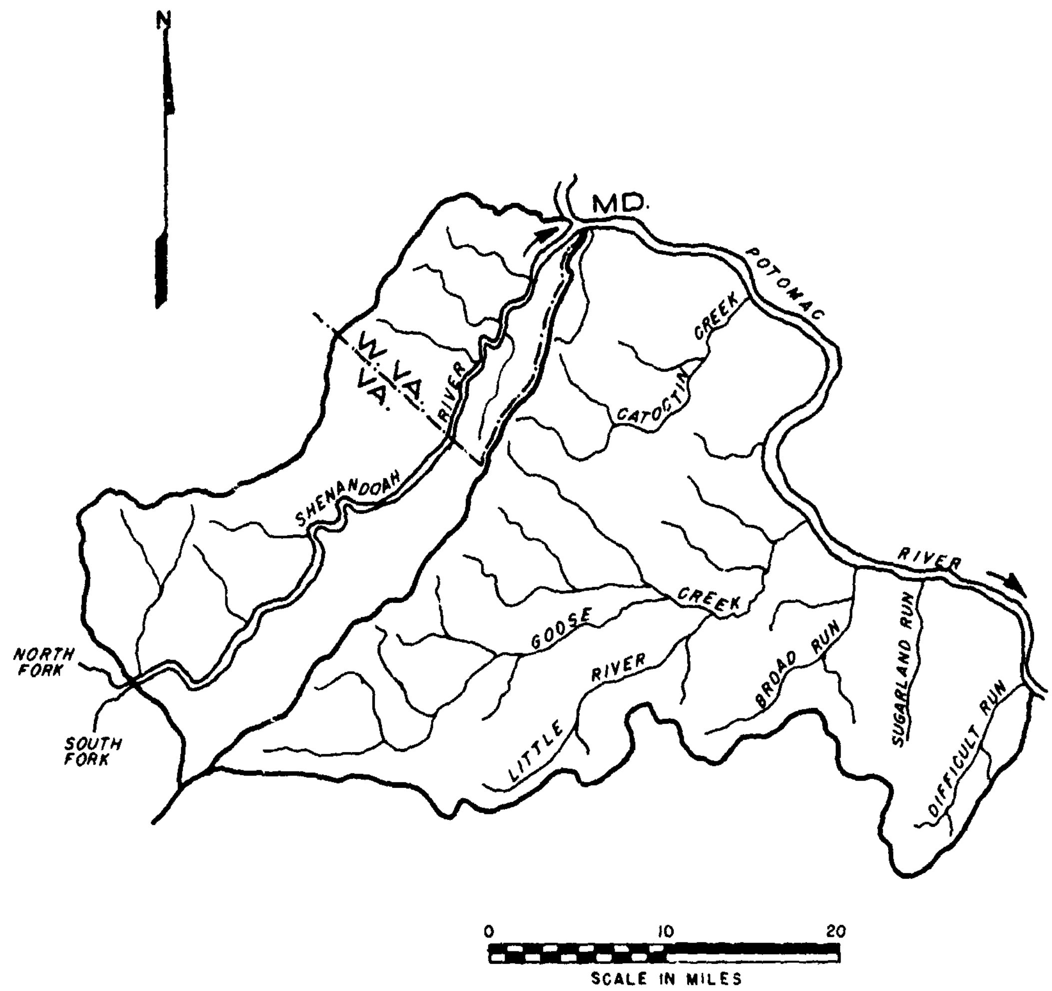
HYDROLOGICAL DATA

The U. S. Geological Survey maintains 13 gaging stations throughout the Shenandoah drainage system. Ten of these stations are located on major tributary streams. There are two gaging stations on the North River, one each on the South and Middle Rivers, two on the South Fork, three on the North Fork, and one on the Main Stem of the Shenandoah River. Table 24 shows the gaging station locations, drain-areas gaged, and average, maximum, and minimum discharges recorded for the years specified.



MIDDLE SHENANDOAH RIVER BASIN

FIGURE 41



LOWER SHENANDOAH RIVER BASIN
INCLUDING MINOR POTOMAC SUB-BASINS

FIGURE 42

Table 22

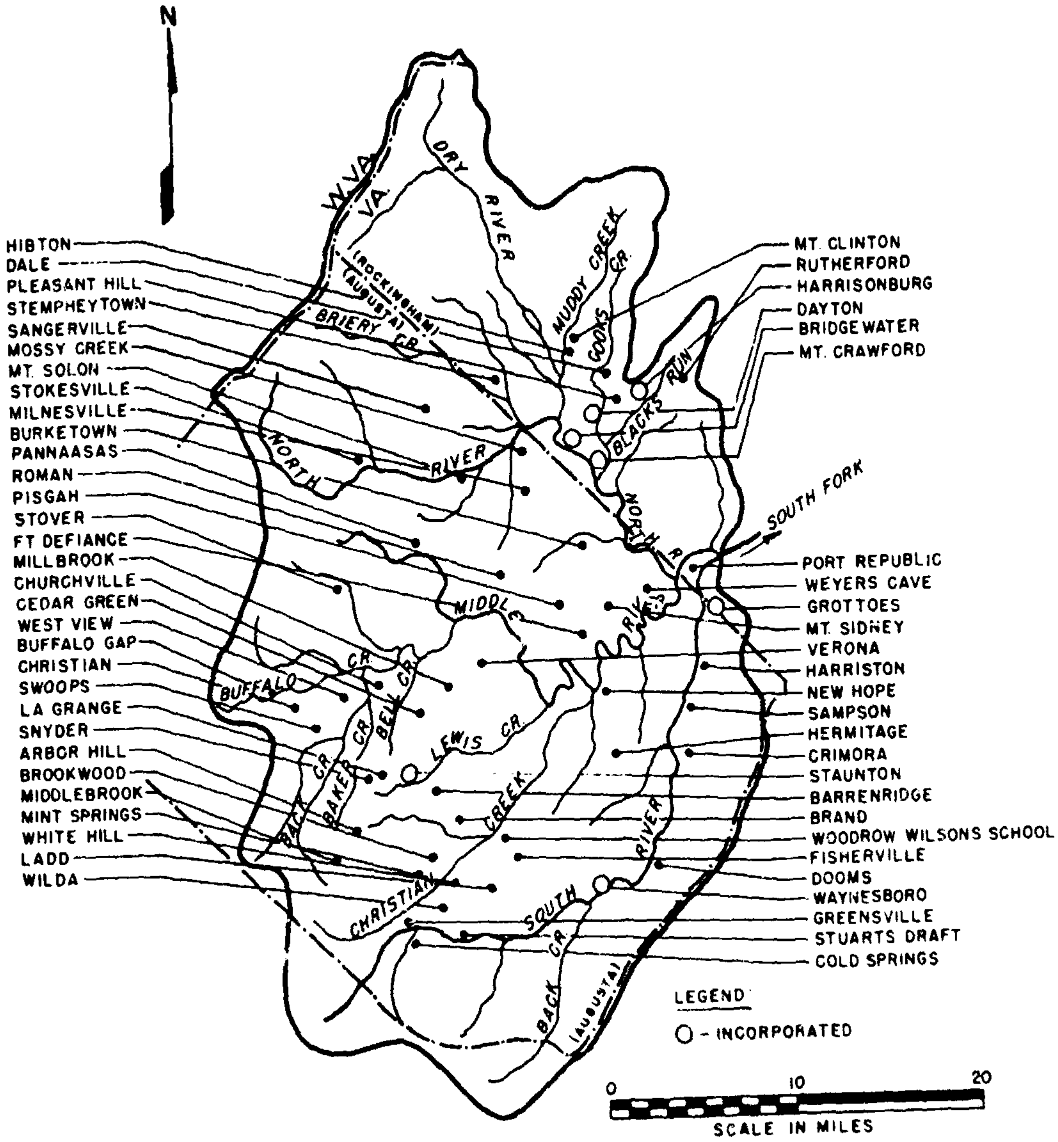
Shenandoah Basin Municipalities
Incorporated Population

Municipality	1950 Census Population	1960 Est. Population
Staunton, Va.	19,927	22,650
Waynesboro, Va.	12,357	15,500
Harrisonburg, Va.	10,810	11,900
Front Royal, Va.	8,115	9,000
Luray, Va.	2,730	4,500
Charles Town, W. Va.	3,035	3,500
Strasburg, Va.	2,020	2,700
Shenandoah, Va.	1,900	2,000
Woodstock, Va.	1,815	2,100
Bridgewater, Va.	1,530	2,000
Harpers Ferry & Bolivar, W. Va.	1,460	2,000
Ranson, W. Va.	1,435	1,500
Berryville, Va.	1,400	1,750
Elkton, Va.	1,360	1,700
Grottoes, Va.	910	1,200
Timberville, Va.	270	1,000
New Market, Va.	700	1,000
Dayton, Va.	790	900

Table 22
(Continued)

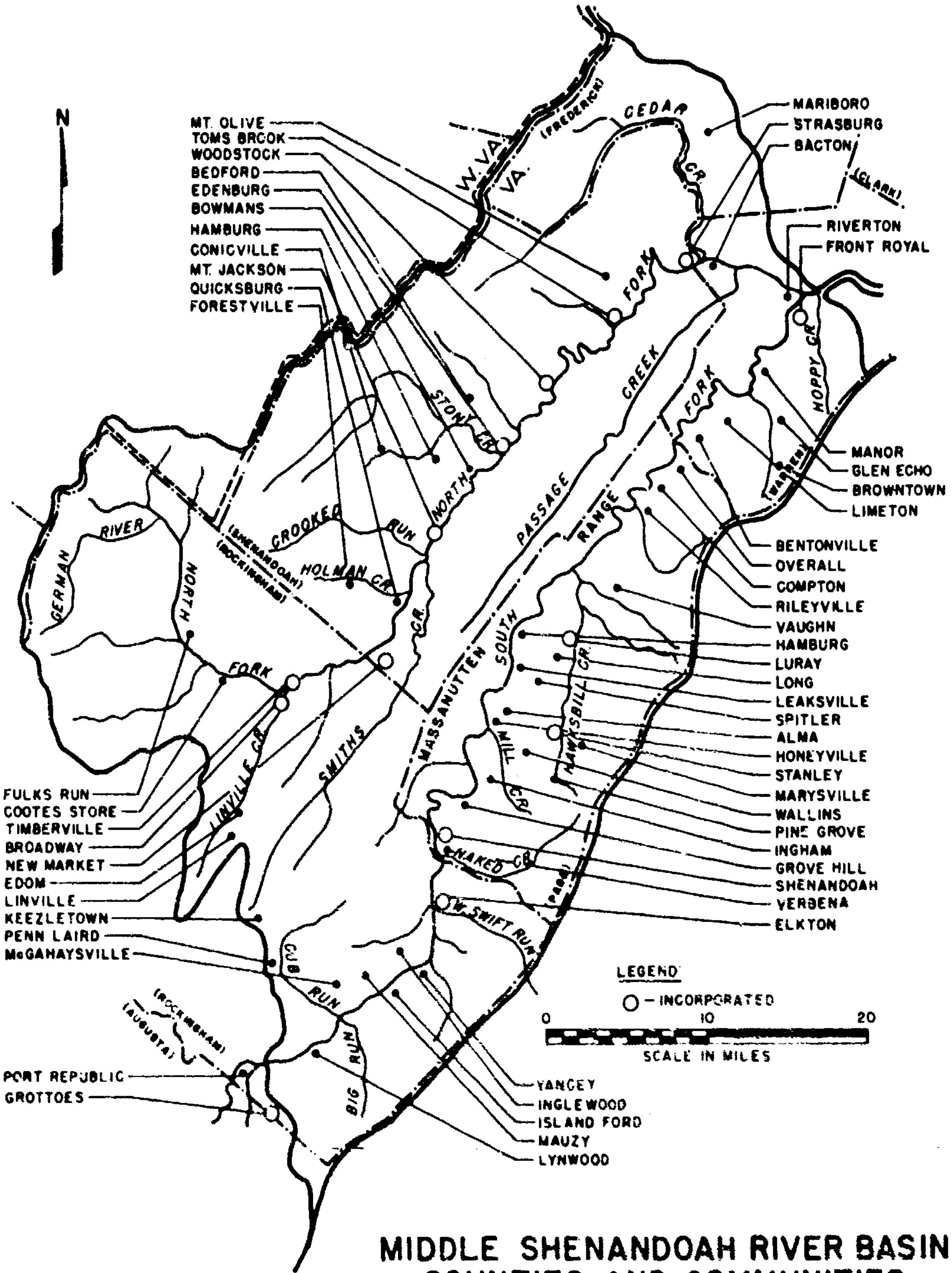
Shenandoah Basin Municipalities
Incorporated Population

Municipality	1950 Census Population	1960 Est. Population
Mt. Jackson, Va.	730	800
Stephans City, Va.	675	700
Broadway, Va.	560	600
Edinburg, Va.	530	550
Stanley, Va.	400	450
Middletown, Va.	385	400
Boyce, Va.	370	400
Mt. Crawford, Va.	300	350
Toms Brook, Va.	250	300
TOTALS	76,764	91,450



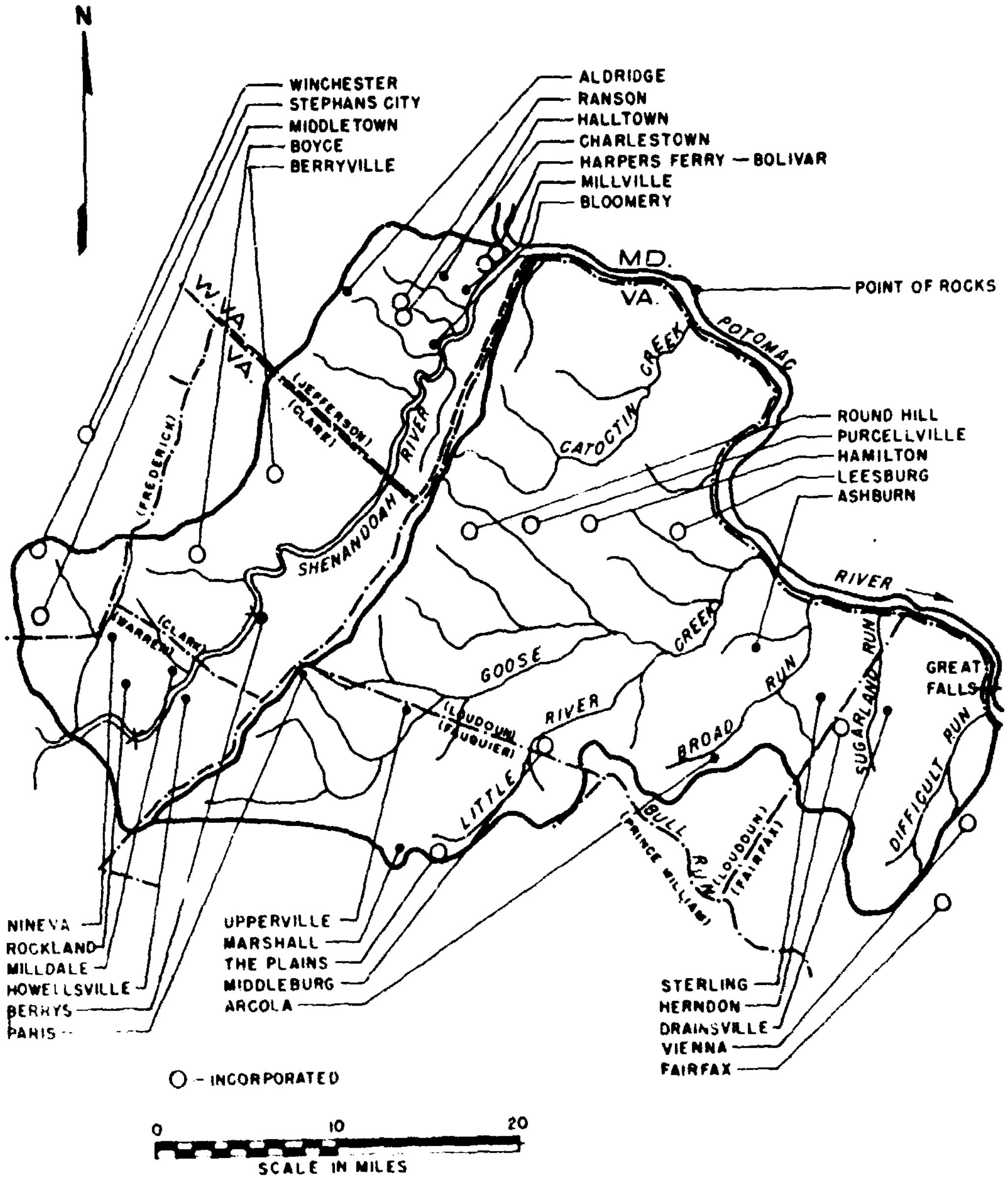
UPPER SHENANDOAH RIVER BASIN
THREE RIVERS AREA
COUNTIES AND COMMUNITIES

FIGURE 43



MIDDLE SHENANDOAH RIVER BASIN
COUNTIES AND COMMUNITIES

FIGURE 44



LOWER SHENANDOAH RIVER BASIN
INCLUDING MINOR POTOMAC SUB-BASINS
COUNTIES AND COMMUNITIES

FIGURE 45

Table 23

Interbasin Industrial Products
Shenandoah Basin

City-County	Product
"Three Rivers Area"	
Waynesboro, Va.	Acetate yarn and acrylic fiber
Augusta	Corduroys and velveteens
	Specialty electric controls
	Saran and nylon fiber
	Preserved wood products
	Vinegar and flavored drinks
	Stone products
	Agricultural chemicals
	Poultry and meat products
	Lumber
	Dairy products
	Feeds and fertilizers
	Electrical power
	Concrete
Staunton-Verona, Va.	Safety razors
Augusta	Heating and air conditioning equipment
	Hosiery
	Clothing
	Textiles - worsted
	Baked foods
	Feeds and fertilizers
	Furniture
	Stone products
	Agricultural lime
	Canned fruit
	Industrial equipment
	Flour
	Asphalt products
	Containers
	Dairy products
	Plating products
	Soft drinks

Table 23
(Continued)

Interbasin Industrial Products
Shenandoah Basin

City-County	Product
"Three Rivers Area"	
Harrisonburg, Va. Rockingham	Poultry
	Metals
	Electronics
	Furniture
	Feeds and fertilizers
	Paper boxes and bags
	Oil refining
	Plastic products
	Potato chips
	Stone products
	Poultry rendering
	Wood products
	Steel fabrication
	Soft drinks
	Asphalt products
	Dairy products
	Concrete products
Bridgewater, Va. Rockingham	Furniture
	Textiles
	Feeds and fertilizers
Grottoes, Va. Augusta-Rockingham	Plastic film
	Feeds
Dayton, Va. Rockingham	Poultry
	Feeds
Middle Basin Area	
Front Royal, Va. Warren	Rayon fabric
	Industrial chemicals
	Agricultural chemicals

Table 23
(Continued)

Interbasin Industrial Products
Shenandoah Basin

City-County	Product
Middle Basin Area	
Front Royal, Va.	Processed fruits
Warren	Processed meats
	Lime and stone
	Concrete
	Dairy products
	Textiles
	Fabrics
	Feeds and fertilizers
	Power
Luray, Va.	Tanned hides
Page	Feeds and fertilizers
Strasburg	Processed fruits
Shenandoah	Creamery
	Lime and stone
	Boats
	Feeds and fertilizers
Woodstock, Va.	Clothing - aprons
Shenandoah	Clothing - overalls
	Designing and manufacturing
	Dairy products
	Feeds and fertilizers
	Machine and chemical supplies
Elkton, Va.	Pharmaceuticals
Page	Clothing
	Stone products
	Soft drinks
	Feeds and fertilizers

Table 23
(Continued)

Interbasin Industrial Products
Shenandoah Basin

City-County	Product
Middle Basin Area	
Broadway, Va. Shenandoah	Paper and cloth bags Feeds and fertilizers Dairy products Poultry rendering
Timberville, Va. Shenandoah	Meat products Canned foods Poultry Dog food
New Market, Va. Shenandoah	Feeds and fertilizers Farm supplies
Mt. Jackson, Va. Shenandoah	Fruit products Concrete products Clothing - overalls Agricultural chemicals Feeds and fertilizers
Lower Basin Area	
Charles Town - Ranson & Halltown, W. Va.	Paper boxboard Stone products Cement Fertilizers Insecticides
Berryville, W. Va. Jefferson	Fruit products Feeds and fertilizers

Table 24

Major U. S. G. S. Gaging Stations and Discharge Summary

Shenandoah Basin Stream Name	Gage Location (Approx.)	Gage D.A. Sq. Mi.	% D.A. at Mouth	Records to 9/57 from	Discharge - cfs		
					Ave.	Max.	Min. Day
North River	Stokesville, Va.	23.4	5.3	10/46	28.2	11,000	0.3
	Burketown, Va.	375	85	6/26	377	62,600	22
Middle River	Grottoes, Va.	360	99.4	6/25	305	24,500	22
South River	Waynesboro, Va.	136	50	10/52	125	13,500	25
South Fork	Lynwood, Va.	1,076	65.2	9/30	990	80,000	93
	Front Royal, Va.	1,638	99.2	9/30	1,633	130,000	103
North Fork	Cootes Store, Va.	215	20.8	9/25	184	50,000	0.2
	Mt. Jackson, Va.	509	49.3	10/43	362	30,000	13
	Strasburg, Va.	772	74.8	3/25	571	100,000	41
Shenandoah River	Millville, W. Va.	3,040	99.5	8/28	2,527	230,000	194

Water Sources and Supplies

There are essentially 30 central water systems serving domestic (institution and sanitary district) and municipal purposes in the Shenandoah Basin. These systems serve about 128,000 persons within and outside of corporate jurisdictions and provide necessary water for many commercial and small industrial uses. The average pumpage for these uses is approximately 13.5 million gallons per day (MGD), of which 76 per cent is obtained from surface sources and the balance from wells and springs.

There are also 12 industrial water supplies in the basin serving average water requirements of 100 MGD. About 85 per cent of industrial water used is obtained from surface sources with the balance taken from wells and springs. Eighty-two per cent of industrial water is used for cooling and the balance for processing purposes.

Approximately one-half (6.8 MGD) of all water used for domestic and municipal purposes and about 17 per cent (16.8 MGD) of the industrial water used in the basin occurs in the "Three Rivers" area, i.e., Waynesboro, Staunton, Harrisonburg, and respective vicinities (35 per cent of the total basin area). Surface water sources in the "Three Rivers" area supply about 70 per cent of the municipal and industrial water used.

The usage of water for municipal and industrial purposes within the entire South Fork drainage system (includes "Three Rivers" area) averages 37.7 MGD as compared with 6.5 MGD within the North Fork system, and 69.0 MGD along the Main Stem of the Shenandoah River. The portions of water supplied from surface sources within the South Fork, North Fork, and Main Stem Shenandoah River system are about 60, 100, and 94 per cent of the total in each area, respectively (see Table 25).

Difficulties in supplying increased demands for water are becoming evident in upper Shenandoah Basin regions. These relatively dry regions, namely, the "Three Rivers" and upper North Fork areas (Augusta and Rockingham Counties), are showing the most rapid industrial and population growth of all other sections in the basin.

There are nine major water systems in the "Three Rivers" area and four major water systems in the upper North Fork area. Following are descriptions of these 13 major water supply systems.

TABLE 25

Water Sources and Supplies (Municipal and Industrial)

Location of Municipality or Industry	Population Served	Municipal - gpd		Industrial - gpd	
		Ground	Surface	Ground	Surface
South Fork Shenandoah					
North River					
Bridgewater, Va.	2,000	150,000			
Dayton, Va.	1,120	140,000			
Mt. Crawford, Va.	300	25,000			
Harrisonburg, Va.	14,000		2,000,000		
Middle River					
American Safety Razor Co., Va.	1,200		144,000		
Staunton, Va.	25,000		1,823,000		
Western State Hospital	3,500		315,000		
Woodrow Wilson School	4,500		112,000		
South River					
South River Sanitary District, Va.	5,000		400,000		
Waynesboro, Va.	17,250	1,750,000			
E. I. Dupont de Nemours				1,725,000	11,155,000
Crompton Shenandoah Co.				2,213,000	
Grottoes, Va.	1,200	110,000			
Reynolds Metals Co.				1,730,000	
South Fork Shenandoah					
Main Stem, South Fork					
Elkton, Va.	1,700	210,000			
Merck and Co.				7,300,000	
Shenandoah, Va.	2,000	250,000			
Stanley, Va.	400	50,000			
Luray, Va.	3,500		290,000		
Virginia Oaks Tannery					280,000
Stauffer Chemical Co., Va.					25,000
Front Royal, Va.	9,200		1,000,000		
American Viscose Corp.			55,000		4,620,000
North Fork Shenandoah					
Broadway, Va.	800		75,000		
Rockingham Poultry Co-op.					545,000
Shen-Valley Packers					200,000
National Fruit Company				25,000	225,000
Timberville, Va.	1,100		105,000		
Valley Housing Corp., Va.	300		37,000		
New Market, Va.	1,000		125,000		
Va. Public Service Co.					1,500,000
North Fork Shenandoah					
Mount Jackson, Va.	800		100,000		
Edinburg, Va.	550		65,000		
Woodstock, Va.	2,100		210,000		
Toms Brook, Va.	300		30,000		
Strasburg, Va.	2,700		300,000		
Winchester, Va.	20,000		3,300,000		
Shenandoah River					
Potomac Edison Co., Va.					43,200,000
Stephens City, Va.	700		60,000		
Middletown, Va.	400		35,000		
Boyce, Va.	400		35,000		
Berryville, Va.	1,750	220,000			
Ranson, W. Va.	500	60,000			
Charles Town, W. Va.	2,500	310,000			
Valley Paper Board Co., W. Va.				2,225,000	
Michigan Limestone Division, W. Va.					530,000
Blair Limestone, W. Va.				730,000	
Potomac Edison Company, W. Va.					21,600,000
SUBTOTALS		3,275,000	10,316,000	15,948,000	83,880,000
TOTALS	137,770	13,591,000		99,828,000	

"Three Rivers" Area - South River System

South River Sanitary District

This sanitary district serves approximately 5,000 people in the Stuarts Draft - Amherst area. Water is obtained from an impoundment on Coles Run of the South River located three miles east of Stuarts Draft, Virginia. The impoundment has a capacity of 100 million gallons with a firm yield of 750,000 gallons per day (gpd). In order to meet increasing demands for water, the district is planning for an impoundment on Mill Creek located near the Coles Run impoundment. This impoundment will also have a storage capacity of 100 million gallons. Preliminary plans also include impoundments on Johns Run and Kennedy Creek, which are also located in the general area of Coles Run and proposed Mill Creek impoundment. The dependable flow of Johns Run is approximately 250,000 gpd and that of Kennedy Creek about 400,000 gpd. It is estimated by the district that within five to eight years all four of the above mentioned supplies will be in use.

Preliminary consideration is being given to the development of a water supply on the St. Marys River, which is a tributary to the James River and to the use of storage capacity from the possible Corps of Engineers or Soil Conservation dam on Middle River north of Staunton, Virginia.

It is estimated by the District that the water needs of the sanitary district will be four times the present use by the year 1970. At that time, it is estimated that the four water supplies just mentioned plus the Middle River and St. Marys River sources will be needed.

The sanitary district water mains are presently interconnected with the Waynesboro, Virginia, system for emergency purposes only. It is expected that in the future the sanitary district will serve areas around and between the Staunton and Waynesboro water supply facilities.

Waynesboro, Virginia

The city of Waynesboro presently obtains water from Coiner Spring located about two miles from the city. The firm yield of the spring is about two MGD and requires treatment for hardness reduction. The water system serves over 17,000 persons and about 400 commercial firms and small business establishments. The most recent additional user of the supply is the new General Electric plant which uses over five million gallons of water per month. The city also maintains a water main to the Dupont plant for fire protection and to the Crompton Shenandoah plant for sanitary use. At times of peak water demand approximately one MGD is available from the South River sanitary district. Two additional spring supplies are available for future use, if needed. The firm yield of these springs is five to

six MGD which together with the two sources mentioned above amount to a total available supply of nearly nine MGD. According to city officials the present supply is considered adequate to meet the needs until approximately the year 1970.

Dupont and Crompton Shenandoah Companies

Both of these plants located at Waynesboro obtain part of their water from Baker Spring. The spring, once owned by the Crompton Shenandoah Company, now belongs to Dupont. The firm yield of the spring is six to seven MGD of which rights to three MGD are retained by the Crompton Shenandoah Company. The Dupont plant also has five wells and an intake on the South River above the plant. Average water use by Dupont is approximately 13 MGD. Water used for cooling is obtained from the river at the rate of 8,000 - 12,000 gallons per minute (gpm) and the wells and spring provide the necessary process and domestic water. A Waynesboro water main connects to the Dupont plant for fire protection only.

The Crompton Shenandoah Company uses about three MGD from Baker Spring during the summer months and about two MGD the remainder of the time. Part of this water is treated for hardness reduction for special process uses. Water for sanitary use at the plant is obtained from the Waynesboro city supply.

Reynolds Metals Company

This company, located at Grottoes, Virginia, obtains water for plant use from 3 wells having a maximum yield of 3,600 gpm. The plant uses one to two MGD mostly for cooling purposes. Plant officials anticipate that water use by about the year 1970 will be double present use.

"Three Rivers" Area - Middle River System

Staunton, Virginia

The city of Staunton obtains water from a mountain reservoir on the North River approximately 20 miles northwest of the city. The firm yield of the impoundment is approximately two MGD. The impoundment was provided as a substitute for the former Gardner Spring source on the Middle River. Gardner Spring has a firm yield of six MGD and requires treatment for hardness reduction. The largest single users of water from the Staunton supply are the new Westinghouse plant at Verona, the Western State Hospital which houses approximately 3,500 patients, and the Woodrow Wilson School which houses approximately 4,500 persons. In addition to these large single water users the supply serves approximately 25,000 persons and over 500 commercial and small business establishments.

The North River impoundment is being used to capacity at the present time. When this capacity is exceeded, the six MGD from Gardner Spring will then be available to supplement this supply.

The American Safety Razor Company near Staunton has its own supply on the Middle River from which approximately 150,000 gpd are taken.

"Three Rivers" Area - North River System

Bridgewater, Virginia

The source of water for municipal use at Bridgewater is Warm Spring located one mile south of town. The firm yield of the spring is 350,000 gpd and requires treatment for hardness reduction. More than 2,000 persons, including Bridgewater College and several small industries and commercial establishments, are served by this supply. About one-half of the firm yield of the spring is pumped during maximum use periods.

The town has purchased a site for a filtration plant on the North River. Construction of the plant is expected to take place sometime before 1970. Upon completion of the filtration plant, the existing spring and reservoir facilities will be abandoned with the possibility that the neighboring town of Mount Crawford will utilize this water supply source.

During the past 5 years the average water use at Bridgewater has increased from 125,000 gpd to 150,000 gpd. Local interests express optimistic views for rapid future development based on past five year growth and the prospect of a new industry, plus expansion of Bridgewater College.

A small spring supply from which 150,000 gpd are taken also serves the nearby town of Dayton.

Harrisonburg, Virginia

This community obtains water from an underground gallery on Dry Creek located about 15 miles west of the city. The gallery has a firm yield of approximately two MGD. Harrisonburg's water demand exceeds this quantity during the three dry months of the year at which times the supply is supplemented locally by water from Silver Lake, which has sufficient capacity to provide an additional two to three MGD. Water from Silver Lake requires treatment for hardness reduction.

The Harrisonburg water system serves approximately 11,500 persons within and 2,500 persons outside the city limits. The system also supplies several poultry plants, a milk cooperative, Madison College for Girls, and over 300 commercial and small business establishments. City planners and area development interests express

recognition of possible limitations in industrial development resulting from an inability to satisfy industrial water requirements.

Upper North Fork Area

Broadway, Virginia

This community obtains water for municipal use from the North Fork at an average rate of 75,000 gpd. The supply serves about 800 persons, 20 commercial establishments, and the Lee Clothing plant which recently located in the area. The only foreseeable change to be made in the system is the addition of a 200,000 gallon storage tank to accommodate the Lee Clothing Company requirements. Since there are no definite plans to expand the filtration plant, the additional water to be supplied to the Lee Clothing Company will be provided by extending the normal operating time of the existing plant. There are no local opinions on future development of the area nor are there plans to integrate supplies with a neighboring industrial water supply cooperative or the town of Timberville.

Rockingham Poultry Marketing Co-op, Shen-Valley Meat Packers, Inc., and National Fruit Company

These industries, located between Broadway and Timberville, have organized to jointly construct and operate a water purification plant, taking water from the North Fork. According to local information, ground water in the area is of unsatisfactory quality and quantity to meet the food processing needs of these plants. The purification plant has a capacity of 1 MGD of which about 200,000 gpd are used by Shen-Valley Packers, and 550,000 gpd by the Rockingham Poultry Co-op. During canning seasons the National Fruit Company uses the remaining water to the system's capacity, plus additional water from Timberville and a small well. The industries are considering expanding the North Fork system by 50 per cent of existing capacity to alleviate difficulties encountered during peak demand periods.

Timberville, Virginia

The major source of water for municipal use at Timberville is a spring on Fork Run. A well is available to supplement this supply when needed. Approximately 1,100 persons and 30 commercial establishments are served by the system. The firm yield of the spring is 200,000 gpd and the well provides approximately 60,000 gpd during the spring and summer, and 10,000 gpd during the fall and winter seasons. During maximum usage periods the entire capacity of the spring is used. The well was drilled in an effort to avert occasional shortages and to provide capacity to meet increasing demands. It is expected that within the next 5 years the average daily demand will be double the present 100,000 gpd. Local authorities predict that should the present rate of growth continue, the North Fork may be utilized as a source of water by the year 1970.

The only other relatively large user of water in the upper North Fork area is the Virginia Public Service Company at New Market which uses approximately 1.5 MGD from the North Fork for cooling purposes.

Middle Basin Area - North Fork and South Fork System

Municipalities on the middle and lower North Fork system; namely New Market, Mt. Jackson, Edinburg, Woodstock, Toms Brook, and Strasburg, together use less than one MGD. Sufficient water is available at each of these locations to supply reasonable demand increases relative to existing requirements for the foreseeable future. Similarly, the communities of Grottoes, Elkton, Shenandoah, Stanley, and Luray, located along the South Fork system, by virtue of their locations with respect to size of drainage areas contributing to stream flow and in view of the availability of ground water would not be expected to require greater quantities of water than could be provided from available sources for the foreseeable future.

An abundance of ground water exists along the South Fork as evidenced by the ground water supply at Merck and Company near Elkton. The Merck and Company plant is the largest single water user in this section of the Shenandoah Basin, using more than seven MGD or more than four times the total of that used by all municipalities along the South Fork (excludes Front Royal area). Water is pumped from 9 wells which range in depth from 68 to 390 feet. Five of the wells are located near the South Fork at the site of an artesian well known as Yancey Spring. Production of the wells along the river is influenced by the water level in the river. Well water is of good quality (hardness - 86 ppm; sulfate - 5 ppm; and iron - < 0.15 ppm), and is considered by Company officials to be of sufficient quantity to meet foreseeable future requirements. Except for dilution flows required for waste assimilation the stream flow of the South Fork is available in addition to ground water at a dependable rate of 60 MGD.

Front Royal, Virginia

Front Royal, Virginia, obtains water from the South Fork and from Happy Creek and Harmony Creek which are tributary to the South Fork immediately upstream from the confluence of the North and South Forks. The system serves more than 9,000 persons, over 300 commercial and small business firms, and 7 industries including the American Agricultural Chemical Company, Allied Chemical and Dye Company, Old Virginia Packing Company, and Schwarzenbach-Huber Textile Manufacturing Company.

The Front Royal municipal system serves an average demand of about one MGD and a maximum demand of 1.8 MGD. A new filtration plant having a capacity of three MGD has recently been constructed and will replace the old plant. In recent years the South Fork has become the major source of water to the area. The dependable supply

of the South Fork is 66.5 MGD at this location. Another source of water available to the area is the North Fork, having a dependable supply of 26.5 MGD.

Other water users in the Front Royal area are the American Viscose Corporation plant and the Potomac Edison Company steam-electric plant. The American Viscose plant uses approximately 5 MGD from the South Fork at Front Royal and the steam-electric plant uses over 43 MGD from the Shenandoah River downstream from Front Royal.

Winchester, Virginia

This city, located in the upper Opequon Creek Basin, obtains water from the North Fork of the Shenandoah River at a point three miles downstream from Strasburg. Water is pumped from a small dam impoundment on the North Fork to the filtration plant at Middletown, Virginia, from which finished water is piped 18 miles along Highway 11 to Winchester. The facility is designed for expansion to 10 MGD which is about one-third of the dependable supply of the stream. The supply serves approximately 14,500 persons within and 3,500 persons outside the Winchester city limits and more than 400 commercial and small business establishments. Average water use is three MGD with estimated maximum demands in excess of four MGD.

Rapid industrial development is expected in the Winchester area. An immediate source of water for industrial use is available from the spring supply once used by the city. The spring yields one MGD during dry periods and two MGD the remainder of the time. This supply is available as an attraction to industrial interests and depending upon quantity requirement would be used until such time as the North Fork system could be expanded or another source developed. According to city officials, for Opequon Creek (located five miles east of Winchester) to be utilized as a water source would require impoundment facilities and an additional filtration plant with water softening facilities. The expense that would be involved in such a project for water supply at Winchester would far exceed further development of the North Fork supply.

Winchester can deliver water to a large area with little difficulty. Water mains presently extend 5 miles to the north of the city and the 24-inch transmission line extending from Middletown could promote considerable development to the south.

Other water sources in the Winchester area (upper Opequon Creek Basin) are a spring supply owned by the Minnesota Mining Company at Middleville, and a spring supply serving the Clearbrook Woolen Co., Inc., Clearbrook, Virginia.

Local authorities expect that the North Fork supply will serve the Winchester area for many years to come provided that water quality is preserved and no significantly great withdrawals of water for irrigation or other purposes occur upstream of the intake.

Lower Basin Area

The major uses of water along the Main Stem of the Shenandoah River are for steam-electric power production, paper boxboard manufacture, and quarrying. In addition to the Potomac Edison Company steam-electric plant at Front Royal (Riverton) this company also has a plant at Millville, West Virginia where approximately 22 MGD are taken from the Shenandoah River for cooling purposes. In the manufacture of paper boxboard the Valley Paper Board Company, located at Halltown, West Virginia, uses approximately 2.3 MGD as obtained from local springs. Total water use for sand washing in the Millville, West Virginia area is about 1.2 MGD of which the Michigan Limestone Division uses 500,000 gpd from local springs and the Blair Limestone Division uses 700,000 gpd from the Shenandoah River. Water used for municipal purposes in this lower basin area is taken mainly from springs.

WASTES AND WASTE LOADS

Domestic Sewage

It is estimated that 101,000 persons or about 80 per cent of those served by water supply systems in the Shenandoah Basin are served by sewage collection systems. The total quantity of treated and raw domestic sewage discharged per day to water courses of the basin in terms of biochemical oxygen demand (BOD_5)* is equivalent to raw wastes from a population of approximately 47,000 persons.** Therefore, the over-all reduction in BOD_5 attributable to sewage treatment facilities in the basin is about 55 per cent. Table VII shows the estimated population served, volumes of waste collected, and population equivalents of waste discharged after treatment, where applicable to specific streams in the Shenandoah River Basin.

Twelve major water-using industries exist in the Shenandoah Basin from which processing wastes and spent cooling water are discharged to basin water courses. The total residual organic waste loads resulting from various degrees of treatment at these plants as measured in terms of BOD_5 is approximately 116,000 population equivalents, or 2.5 times the domestic sewage BOD_5 load. Table 26 shows the location of these industries and volumes of waste, general classification of waste treatment, and corresponding population equivalents discharged to specific streams.

Out of an average of approximately 163,000 population equivalents of BOD_5 received in basin water courses per day, about 38 per cent occurs in the "Three Rivers" area, 56.5 per cent in the middle

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* five-day 20°C. biochemical oxygen demand

** one population equivalent (P.E.) = 0.17 pounds BOD_5 per day

TABLE 26

Wastes and Waste Loads (Municipal and Industrial)

Location and Name of Municipality or Industry	Population Served	Domestic			Industrial		
		GPD	Treat.	P.E. Disch.	GPD	Treat.	P.E. Disch.
South Fork Shenandoah							
North River							
Bridgewater, Va.	2,000	145,000	Prim. (U.C.)	1,300			
Dayton, Va.	1,120	125,000	None	1,120			
Mt. Crawford, Va.	None	(Septic Tanks)		-			
Harrisonburg, Va.	10,500	1,500,000	Sec.	5,450			
Middle River							
Verona Sanitary District	1,500	187,000	Prim.	970			
American Safety Razor Co.	1,200	30,000	Prim.	780	135,000	-	-
Staunton, Va.	22,000	1,450,000	Sec. (U.C.)	5,500			
Western State Hospital	3,500	280,000	Sec.	900			
Woodrow Wilson School	4,500	100,000	Prim.	2,925			
South River							
Waynesboro, Va.	17,250	1,660,000	Sec.	5,200			
E. I. Dupont de Nemours	2,700	70,000	City		[illegible],100,000	Sec.	21,180
Crompton Shenandoah Co.	750	20,000	City	-	[illegible],070,000	Lagoon	16,050
Grottoes, Va.	None	(Septic Tanks)					
Reynolds Metals Co.	1,200	5,000	Prim.	[illegible]	[illegible]	-	-
Main Stem, South Fork							
Elkton, Va.	1,700	190,000	Prim.	1,100			
Merck & Co.	600	15,000	Sec.	150	6,850,000	Sec.	31,620
Shenandoah, Va.	2,000	225,000	None	2,000			
North Fork Shenandoah							
Main Stem South Fork							
Stanley, Va.	400	45,000	None	400			
Luray, Va.	3,500	260,000	Prim.	[illegible]			
Virginia Oaks Tannery	200	[illegible],000	City	-	203,000	Lagoons	6,840
Stauffer Chemical Co.	45	1,500	Sec.	10	23,500	None	-
Front Royal, Va.	9,200	900,000	Prim.	7,500			
American Viscose Corp.	[illegible]	[illegible]	City		4,350,000	Lagoons	27,990
North Fork Shenandoah							
Broadway, Va.	None	(Septic Tanks)					
Rockingham Poultry Co-op	300	7,500	(Plant Lagoons)		503,000	Lagoons	9,810
Shen-Valley Packers	25	600	(Plant Lagoons)		188,000	Lagoons	700
National Fruit Company	150	4,000	Sec.	100	235,000	Lagoons	3,000
Timberville, Va.	None	(Septic Tanks)					
New Market, Va.	1,000	110,000	Prim. (U.C.)	650			
Va. Public Service Co.					1,410,000		
Mount Jackson, Va.	800	90,000	Prim. (U.C.)	500			
Edinburg, Va.	550	60,000	Prim. (U.C.)	350			
Woodstock, Va.	2,100	190,000	Sec.	500			
Toms Brook, Va.	300	(Septic Tanks)					
Strasburg, Va.	2,700	270,000	Prim. (U.C.)	1,750			
Shenandoah River							
Potomac Edison Co.					40,500,000		
Stephens City, Va.	700	54,000	Prim.	450			
Middletown, Va.	400	(Septic Tanks)					
Boyce, Va.	400	(Septic Tanks)					
Berryville, Va.	1,750	200,000	Sec.	450			
Ranson, W. Va.	300	55,000	Prim.	950			
Charles Town, W. Va.	2,500	280,000	Prim.	3,000			
Valley Paper Board Co.	160	4,000	None	160	2,120,000	None	3,600
Michigan Limestone Division					530,000	Lagoons	-
Blair Limestone Division					720,000	Lagoons	-
Potomac Edison Co., W. Va.					20,300,000	-	
TOTALS	102,070			[illegible]			115,790

basin section (North and South Forks), and the remaining 5.5 per cent occurs in the lower or Main Stem Shenandoah section of the basin. Following is a description of waste treatment facilities existing in various sections and at specific locations in the Shenandoah Basin for reducing the pollutional effects of wastes.

"Three Rivers" Area - South River System

Waynesboro, Virginia

Municipal waste treatment facilities at Waynesboro treat approximately 1.7 MGD of domestic sewage as collected from about 4,000 residences, many commercial and business firms, and several relatively large industries. The facilities provide secondary treatment with BOD_5 reductions estimated at 75-80 per cent efficiency. The plant waste effluent, estimated to contain 870 pounds of BOD_5 per day (P.E. 5,200) is received in the South River downstream from the city.

E. I. Dupont de Nemours

Pollution abatement at the Waynesboro works of E. I. Dupont de Nemours & Co., Inc., has been accomplished by in-plant changes, modernizarion of recovery systems, catalytic oxidation of dimethylformamide hydrolysis products, and activated sludge treatment of acrylic plant liquid wastes. Process changes in the acetate rayon plant reduced the BOD_5 waste load by about 70 per cent. The activated sludge waste treatment works was reported to give an efficiency of 95 per cent removal of BOD_5 from the waste being treated. The combined waste load from the Dupont Waynesboro works, discharged from the 6 sewers to the South River, averaged 3,530 pounds (P.E. 21,180) per day during the period March - May 1959. The over-all efficiency of BOD_5 reduction at the plant is approximately 56 per cent.

Crompton Shenandoah Company, Inc.

This plant, located at Waynesboro, has reduced the pollution effects of process wastes through in-plant changes in processes. Outstanding among these developments are:

(a) substitution of carboxymethyl cellulose (cmc) for a portion of the starch required in the slashing process for corduroy and velveteen;

(b) discontinuance of the use of tallow soap and enzymes to remove starch in the de-sizing process;

(c) substitution of low BOD detergent for soap in the scouring operation;

(d) substitution of sodium perborate for acetic acid used in the dye house on an oxidizing agent in the dyeing of vat colors; and

(e) substitution of low BOD detergent for soap-scouring after printing.

Wastes from the dye house are discharged through a pond which removes lint that would otherwise enter the receiving stream. The pond also permits oxidation of some color by virtue of the wash water containing chlorine from the bleach operation. Waste loads to the South River from the Waynesboro Textile Mill averaged 2,674 pounds BOD_5 (P.E. 16,050) per day during the third quarter of 1959. This represents a 46.5 per cent reduction in the BOD_5 waste load from what it was in 1948, the base year used by the plant from which improvements have been measured.

"Three Rivers" Area - Middle River Systems

Staunton, Virginia

At the present time, municipal waste treatment consists of primary settling of sewage with effluent chlorination. The plant serves approximately 5,500 residences, many commercial and business firms and several industries. Overloading and insufficient treatment in recent years have led to construction of a new secondary treatment plant. It is expected that the new plant will be in operation sometime in 1961. Plant effluents are discharged to Lewis Creek of the Middle River. The effluent load to be received in Lewis Creek from the new plant is expected to be approximately 900 pounds of BOD_5 (P.E. 5,500 per day).

Verona Sanitary District

Establishment of this district has taken place as a result of rapid residential and commercial growth in the Verona, Virginia area. The district has provided collection and primary waste treatment facilities serving more than 300 residences and commercial establishments. Treatment plant effluents containing an estimated daily BOD_5 load of 160 pounds (P.E. 970) are received in the Middle River near Verona.

Individual Waste Treatment Facilities

The American Safety Razor Company, Western State Hospital, and Woodrow Wilson School each have facilities for waste treatment. Table 24 shows the type of treatment and quantities of waste and waste loads discharged from these plants. Effluents from the American Safety Razor Company plant are received in the Middle River near Verona, Virginia, and those from plants at the Western State

Hospital and Woodrow Wilson School are received in Christian Creek of the Middle River located east of Staunton, Virginia.

"Three Rivers" Area - North River System

Bridgewater and Dayton, Virginia

These communities each have collection facilities discharging sewage untreated to the North River. The town of Bridgewater, however, having received a Public Health Service grant, has under construction a primary type treatment plant designed to treat 0.35 MGD. Waste loads received in the North River from the two communities considering primary treatment at Bridgewater are estimated at 400 pounds of BOD_5 (P.E. 2,400) per day.

Harrisonburg, Virginia

Facilities for secondary treatment of wastes are provided at Harrisonburg. The plant handles wastes from more than 2,500 residences, many commercial and small business establishments, and several industries including poultry processing wastes from Swift and Company and the Shenandoah Poultry Co-op. The volume of waste treated per day is in excess of 1.5 MGD. According to plant operators, the treatment works become overloaded occasionally by visceral material from poultry processing. The plant effluent load received in Blacks Run of the North River averages approximately 900 pounds of BOD_5 (P.E. 5,500) per day.

Middle Shenandoah Basin Area - North Fork System

Broadway - Timberville, Virginia

No waste collection facilities exist at either of these locations. Most residences employ septic tanks for treatment of household wastes.

Rockingham Poultry Marketing Co-op, Inc.

Treatment of poultry wastes consists of screening, plain sedimentation, and use of stabilization ponds. Following passage through rotary screens, waste flows through a rectangular basin equipped with a linkbelt sludge skimming and collection device. Sludge is removed and trucked to an open pit and the supernatant effluent is piped to three stabilization ponds operated in series. Emphasis has been placed on removal of liquid wastes from production of the dog food by-product, which accounted for more than half of the total BOD_5 from the plant. Recovery of blood and greases has been stressed. Data indicate no BOD_5 reduction in No. 1 stabilization pond; however, data indicate that the three ponds in series remove about 50 per cent of the BOD_5 which enters the No. 1 unit. The average BOD_5 load to the North Fork from this source amounts to about 1,635 pounds (P.E. 9,800) per day, 5 days per week.

Shen-Valley Meat Packers, Inc.

Water is used for process, cooker condensers, and sanitary purposes. It is estimated that one-half of the water used is for process and sanitary wastes and the other half for condenser water. The average BOD_5 concentration of the untreated process wastes is approximately 2,000 parts per million (ppm). Treated process wastes average 100 ppm as discharged to the North Fork. Condenser water discharged to the river has a BOD_5 of 40 ppm. Wastes having been settled in a sedimentation tank flow to two stabilization ponds operating in series. The system provides up to 95 per cent BOD_5 removal and efficient removal of suspended solids. Condenser water flows directly to the river after passing through a grease trap and an outfall sewer bedded with trap rock. Particular emphasis has been placed on recovery. It is evident by observation that the recovery systems are efficient in removal of grease, blood, and paunch manure from the sewers. The average BOD_5 load to the stream amounts to 117 pounds of BOD_5 (P.E. 700) per day, 5 days per week.

National Fruit Company

This plant operates on a seasonal basis during the months of August through November and produces applesauce and vinegar. Waste treatment includes separation, drying, and land disposal of solids material, spray dispersion of liquid waste on percolation fields, and lagooning (two lagoons) of excess fluid wastes. Minimum detention time in the lagoons is about three weeks. Lagooned effluents are released to the North Fork in batches of 150,000 to 175,000 gallons. It is estimated that approximately 75 per cent BOD_5 removal is accomplished by these treatment methods and that the effluent received in the North Fork contains an average of 500 pounds of BOD_5 (P.E. 3,000) per day, 5 days per week during the canning season.

Miscellaneous Waste Sources

The communities of New Market, Mount Jackson, Edinburg, Woodstock, and Strasburg, Virginia, each discharge sewage wastes to the North Fork. New Market, Mount Jackson, and Strasburg have no sewage treatment at the present time. However, it is expected that these three communities will soon provide primary treatment of wastes as required by the Virginia State Water Control Board. Edinburg has recently constructed a primary treatment plant in compliance with the State requirement for this city. Waste treatment at Woodstock is accomplished with secondary treatment facilities. Respective waste loads discharged by each municipality are shown in Table 26.

Middle Shenandoah Basin Area - South Fork System

Merck and Company, Inc.

This plant, located near Elkton, Virginia, manufactures pharmaceuticals and antibiotics (fine chemicals and medicinal chemicals). All liquid process wastes are discharged to a common sewer leading to the waste treatment works. Sanitary wastes are collected in a sanitary sewer which discharges to a Clarigester. Solid wastes in the form of filter cakes and trash are incinerated in a coverable dumping area. Normal production places a waste load of 20,000 pounds BOD_5 per day on the treatment plant. The average flow to the plant is 1.2 MGD which includes sanitary wastes. Process wastes and effluent from the Clarigester are treated by activated sludge, air floatation, and biofilters in series. The waste load discharged from the plant to the South Fork of the Shenandoah River ranged from a minimum of 3,000 to a maximum of 7,700 (P.E. 18,000-46,200), with an average of 5,270 pounds BOD_5 (P.E. 31,620) per day during the period July 1, 1958, through June 30, 1959.

Miscellaneous Waste Sources

Elkton, Shenandoah, Stanley, and Luray, Virginia, each discharge wastes to the South Fork. Primary treatment facilities exist at Elkton and Luray. Shenandoah and Stanley have no waste treatment. Municipal waste loads from Elkton and Shenandoah are received directly in the South Fork whereas those from Stanley and Luray are received in Hawksbill Creek of the South Fork. The respective loads discharged from each municipality are shown in Table 26.

Virginia Oaks Tannery, Inc.

This industry, located at Luray, Virginia, produces approximately 35,000 pounds of leather per day, operating 8 hours per day and 5 days per week. Concentrated wastes from the beam house are passed over a linkbelt vibrating screen for removal of hair and fleshings. Screened waste and spent tan liquor flow to a primary settling tank whereas weak wastes from certain vats and washups bypass the settling tank to two settling ponds. Sludge is removed intermittently to maintain settling efficiency. Supernatant liquor from the primary settling tank is disposed of by spray irrigation from May 1 to November 1. Spray irrigation was started in September 1956 and has resulted in the removal of a significant waste load from Hawksbill Creek and the South Fork during the summer months. During the winter season process wastes from the primary clarifier drain through the two settling ponds into Hawksbill Creek, along with the weaker wastes. The treatment facilities appear to provide BOD_5 removals of about 40 per cent. Average loads to Hawksbill Creek are 1,140 pounds BOD_5 (P.E. 6,840) per day, 5 days per week.

Stauffer Chemical Company

This plant produces 150,000 pounds of carbon bisulfide daily on a continuous basis. It is produced by passing vaporized sulfur over heated charcoal in a retort. By-products from this operation are recovered and re-used in the process. The finished product is stored in tanks surrounded by water. Storage water contains approximately 3 ppm hydrogen sulfide (H_2S). Based on water losses to the sewer and H_2S concentrations, about 0.5 pounds of H_2S would be lost from the process per day. Effluents from the plant discharge to a common ditch leading to Flint Run, which in turn discharges to the South Fork at Karo, Virginia.

Front Royal, Virginia

Municipal wastes at Front Royal receive primary treatment with effluent chlorination before discharge to the South Fork. The treatment works has a capacity for treating wastes from a population of 12,000 persons and is operating at approximately 75 per cent of this capacity. The plant serves about 2,500 residences, many commercial and business firms and handles domestic wastes from several relatively large industries. Happy Creek of the South Fork receives approximately 1,250 pounds of BOD_5 (P.E. 7,500) per day from this plant.

American Viscose Corporation

This industry, located at Front Royal, produces rayon tire cord. Wastes are treated for zinc removal and detained in settling basins for solids and BOD_5 reduction. All wastes, amounting to an average of 4.5 MGD pass through the settling facilities. Plant records for May 1958 through June 1959 show zinc concentrations in the effluent ranging from 0.8 to 34.2 parts per million and averaging about 10.3 ppm. Effluent loads received by the South Fork for the months of April, May, and June 1959 averaged 3,830 pounds BOD_5 (P.E. 23,000)per day.

Lower Shenandoah Basin Area - Main Stem Shenandoah River System

Miscellaneous Municipal Waste Sources

Stephans City and Berryville, Virginia; Ranson and Charles Town, West Virginia, are the only significant sources of municipal waste received in the lower Shenandoah River Basin. Middletown and Boyce, Virginia, presently unsewered, present potential sources of municipal waste. Table 26 shows the treatment and estimated waste loads for these communities.

Valley Paper Board Company

Process wastes amounting to approximately 2.2 MGD are discharged untreated to Spring Run of the Shenandoah River near Halltown, West Virginia. Wastes of varying colors from dye operations are produced and loads on the creek average about 630 pounds BOD_5 (P.E. 3,750) per day including a small amount of partially treated sanitary waste.

WATER QUALITY

Water Quality Criteria

In order to describe relative stream water quality in the Shenandoah River Basin, the water quality criteria as adopted by the Interstate Commission on the Potomac River Basin are used. Table 27 shows the stream use classifications based on those water quality criteria.

The criteria for Class C water are used to identify the stream sections containing water of suitable quality for domestic supplies and industrial processing. It is understood that waters not meeting the Class C criteria are also not suitable for bathing or protection of fish life.

General

The water quality and pollution characteristics of the Shenandoah Basin streams and stream reaches described in the section to follow are based mainly on data collected during the Public Health Service survey of May - June 1960 and partly on samplings by the Virginia State Water Control Board for the period July - December 1959 and by the three major industries (Dupont, Merck, and American Viscose), as reported to the Interstate Commission on the Potomac River Basin for the period July 1958 - June 1959 (see Appendixes IV and V). The samplings made by the Public Health Service near the mouth of the Shenandoah River in West Virginia during September - October 1958 are also included. Figure 46 shows the location of Public Health Service sampling stations and corresponding Virginia and Interstate Commission stations.

As was described previously, the South Fork Shenandoah and its headwater tributaries (North, Middle, and South Rivers) receive by far the greatest quantities and varieties of wastes of all other receiving streams in the Shenandoah Basin. For this reason, more extensive sampling was conducted in this area.

Sampling Results

Of all parameters measured, the numbers of coliform organisms were found to most frequently exceed Class C water quality objectives (see Figure 47). Dissolved oxygen (D.O.) and biochemical

oxygen demand (BOD_5) under conditions of the PHS survey of May - June 1960, except for points in the "Three Rivers Area" were within limits for Class C water quality at most sampling stations (see Figures 48 and 49). Under lower flow conditions as encountered in September - October 1958 the waters near the mouth of the Shenandoah River contained BOD_5 in excess of the Class C water quality objective (Potomac Report - 1959, Part III, Figure 4).

The effects of waste discharges in the "Three Rivers Area" of the South Fork were most evident at sampling points downstream from Waynesboro, Virginia (South River), Staunton, Virginia (Lewis Creek of Middle River), Bridgewater, Virginia (North River), and Harrisonburg, Virginia (Blacks Run of North River). As noted in Figure 47, the stream waters from these sources downstream to the respective confluences with the South Fork contained numbers of coliform organisms in excess of those recommended for raw water supplies requiring complete conventional treatment. No appreciable effect of waste BOD_5 on dissolved oxygen in the Middle and North Rivers was observed under the survey conditions. Significant oxygen depletions, however, were observed at times in Lewis Creek (minimum D.O. - 65% of saturation), and Blacks Run (minimum D.O. - 35% of saturation).

Serious D.O. depletions also exist in the South River downstream from municipal and industrial waste sources at Waynesboro (see Table 28).

It is noted in Table 28 (PHS - Sta. No. S-4) that D.O. recovery is nearly complete by the time the South River waters enter the headwaters of the South Fork. Dissolved oxygen depletion and recovery in this instance occurs within approximately 18 miles of the stream.

By examining the poundages of BOD_5 loads carried in the South Fork and noting additional loads entering along its course, it is apparent that with lower flows than encountered during the May - June 1960 survey, significant D.O. depletions could occur (see Figure 50). Available D.O. data indicate that the greatest depletions occur in the power pool at Shenandoah, Virginia, downstream from Merck and Company at Elkton, Virginia, and near the confluence of the South Fork with the North Fork downstream from Front Royal, Virginia. Table 29 shows the D.O. data relating to these sections of the South Fork.

As was noted in Figure 47, the stream waters at most sampling points on the North and South Forks contained coliform organisms in excess of those specified for Class C water uses. The low level and in some cases lack of sewage treatment is apparently responsible for these conditions, although agricultural runoff waters also contribute to these organisms as particularly noted at Stations S-1, S-5a, and N-1 (stations above waste sources).

TABLE 27

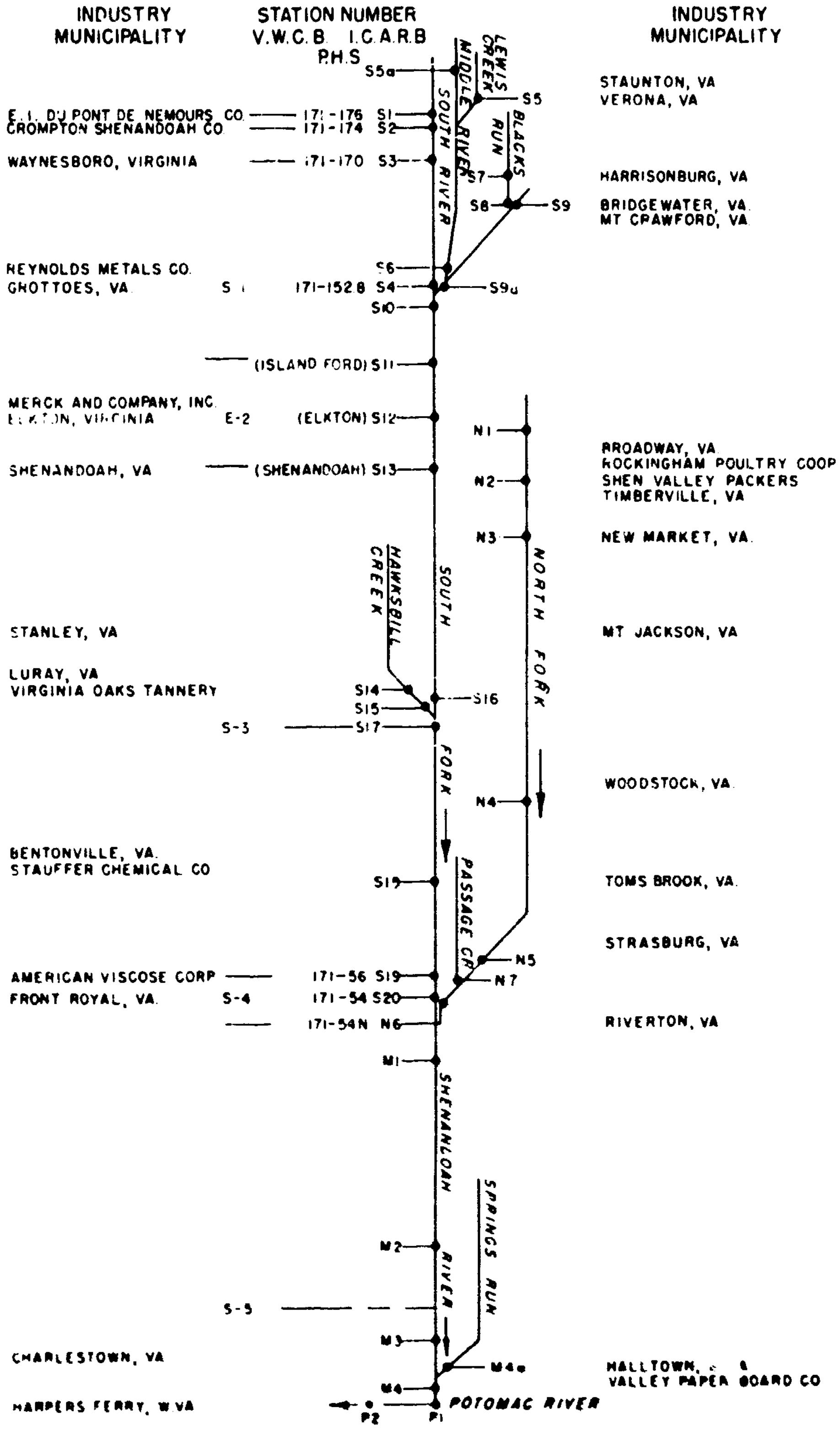
Interstate Commission on the Potomac River Basin

Minimum Water Quality Criteria for Streams
in the Potomac River Basin

Approved 8 August 1946

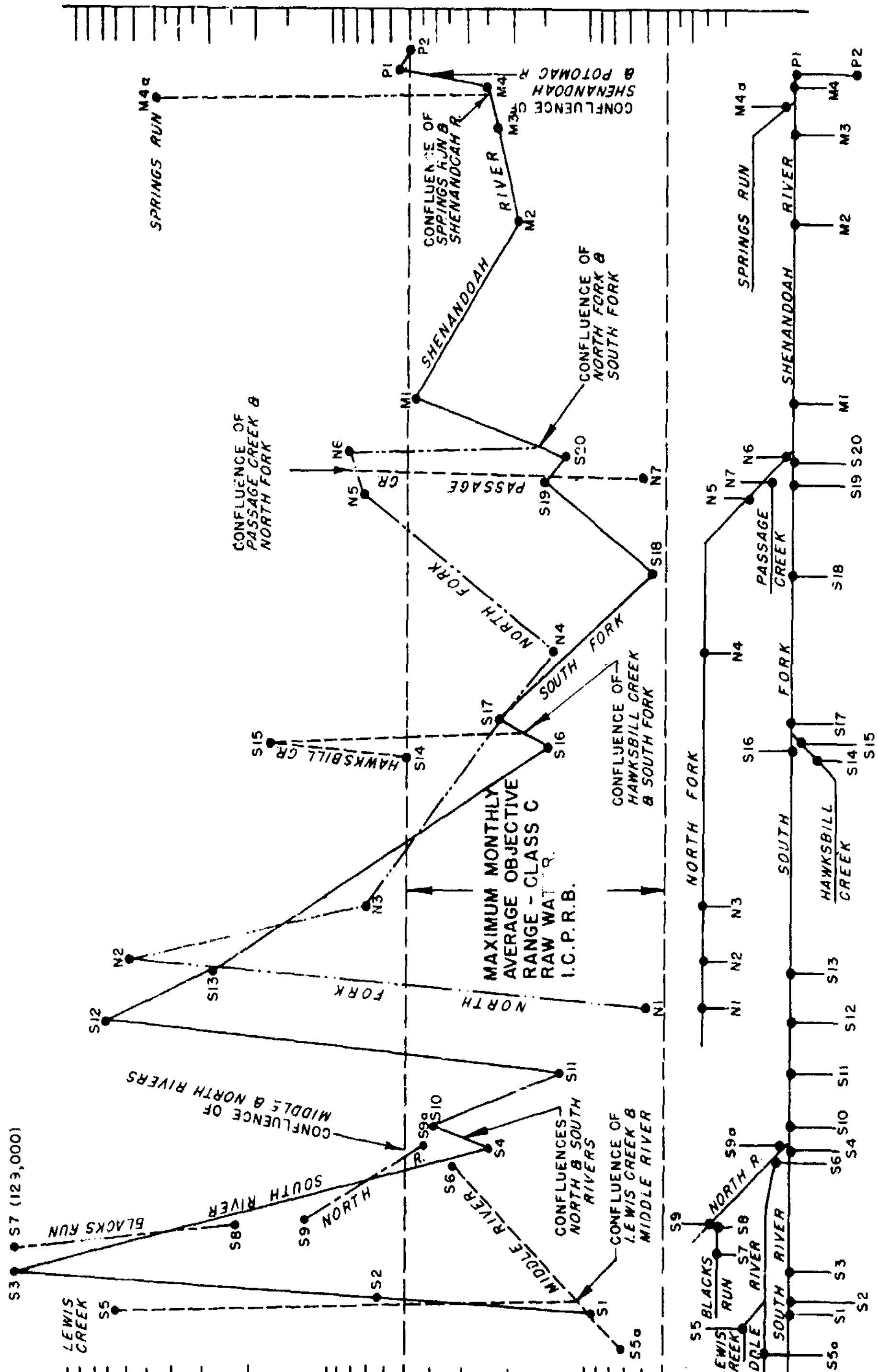
	CLASS A Drinking Water (No treatment except cl.)	CLASS B Bathing, Fish Life	CLASS C Domestic Water Supplies (Before complete treatment) Industrial Process Water	CLASS D General Sanitary Condition - to prevent nuisance
Coliform Bacteria	0 - 50	Mo. av. 50 - 500 Max. not over 1,000	Mo. av. 500 - 5,000	----------
Color, ppm	0 - 10	20 (desirable)	Amt. of color and turbidity allowed which can be removed by standard equipment and practices	----------
Turbidity, ppm	0 - 10	40 (desirable)	----------	----------
pH	6.0 - 8.0	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
5-Day BOD, ppm	----------			
Monthly av., ppm	----------	1.5	2.0	3.0
Max. observation, ppm	----------	3.0	4.0	5.0
Dissolved Oxygen, ppm				
Monthly av., ppm	7.5	6.5	6.5	4.0
Min. observation, ppm	6.5	5.0	5.0	Min. daily ave. 3.0 Absolute min. 2.0
Other Conditions	No toxic substances, oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste - or odor-producing substances.	Same as A	Same as A	No toxic substances, oils, tars, or free acid at any time. No floating solids or debris except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

NOTE: These criteria are to be used only in conjunction with a sanitary survey as a guide in determining the minimum water quality for the various classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.



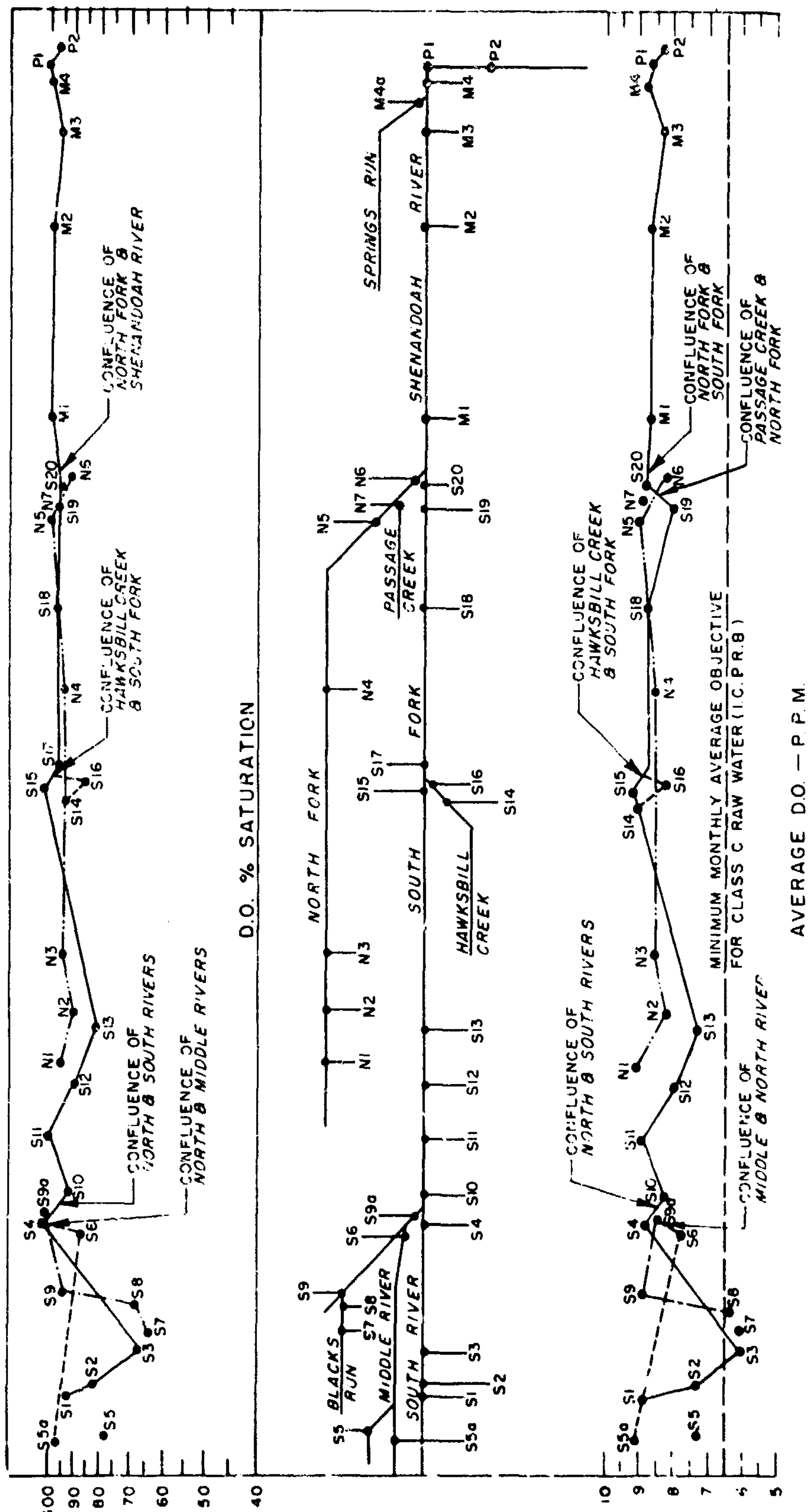
SHENANDOAH RIVER BASIN SURVEY ORIENTATION DIAGRAM

FIGURE 46



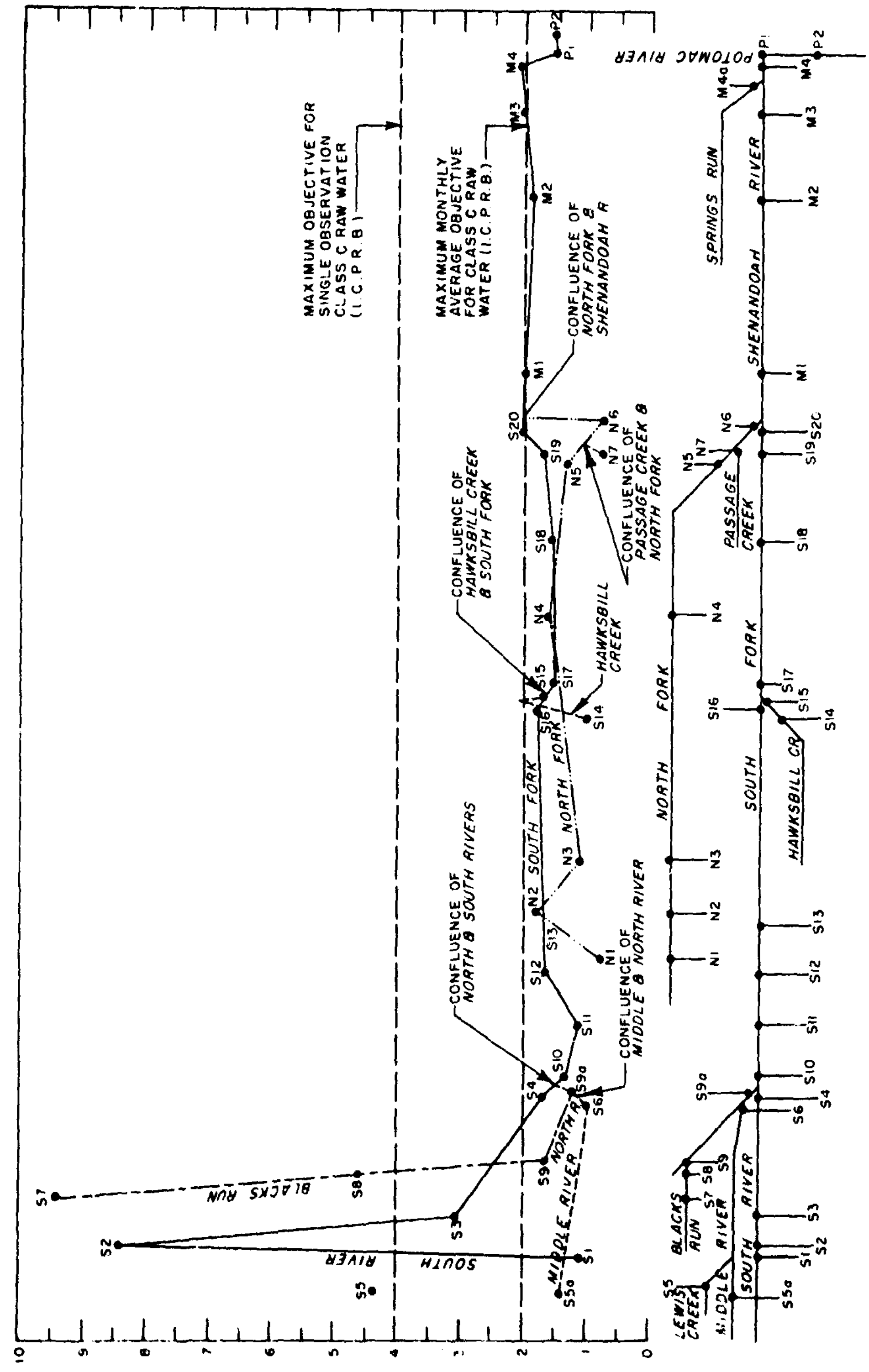
SHENANDOAH RIVER BASIN SURVEY
COLIFORM ORGANISMS PER 100ml (DIRECT MEMBRANE FILTER)
MAY–JUNE, 1960

FIGURE 47



SHENANDOAH RIVER BASIN SURVEY
DISSOLVED OXYGEN RELATIVE TO WATER QUALITY CRITERIA
MAY-JUNE, 1960

FIGURE 48



SHENANDOAH RIVER BASIN STUDY
BIO-CHEMICAL OXYGEN DEMAND RELATIVE TO WATER QUALITY CRITERIA

FIGURE 49

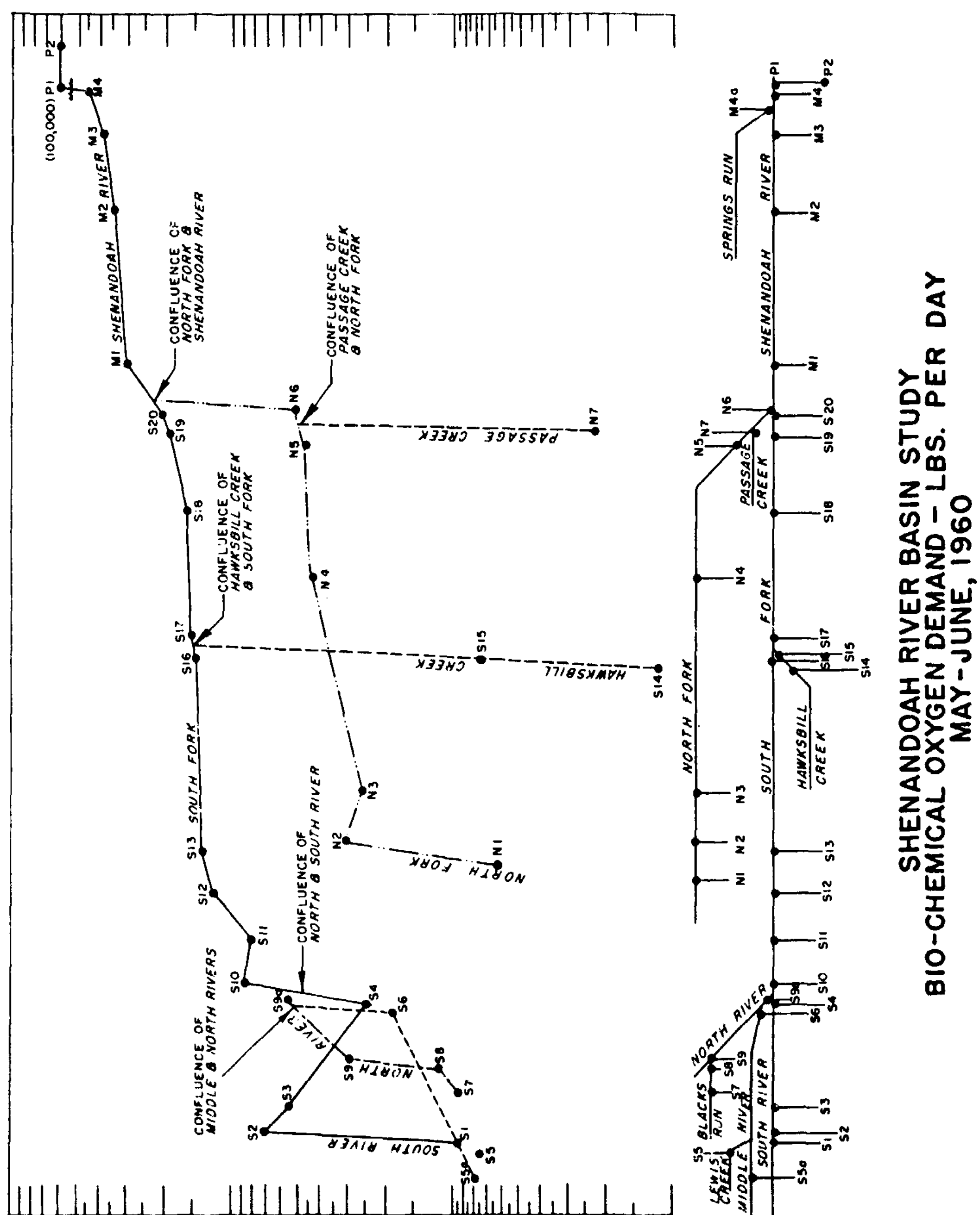

SHENANDOAH RIVER BASIN STUDY
BIO-CHEMICAL OXYGEN DEMAND - LBS. PER DAY
MAY-JUNE, 1960

FIGURE 50

Table 28

South River
D.O. Data Above and Below Waynesboro, Virginia

Location and Source of Data	Station No.	D.O. - ppm Ave.	Max.	Min.
Above Waynesboro				
Interstate Commission	171-176	10.05*	13.0	8.6
PHS	S-1	8.85***	9.55	8.05
Below Waynesboro				
Interstate Commission	171-174	5.2*	11.7	0
PHS	S-2	7.3***	9.0	5.2
Interstate Commission	171-170	6.15*	11.3	3.6
PHS	S-3	6.1***	8.7	4.15
Interstate Commission	171-152.8	11.6*	13.8	8.0
Va. Water Control Bd.	S-1	10.2**	11.6	7.6
PHS	S-4	8.9***	9.5	8.2

*12 samples
**9 samples
***7 samples

Table 29

South Fork Shenandoah
D.O. Data Above and Below Elkton
and Front Royal, Virginia

Location and Source of Data	Station No.	D.O. - ppm Ave.	Max.	Min.
Above Elkton				
Interstate Commission	(Island Ford)	11.6*	15.2	8.1
PHS	S-11	8.90***	9.55	8.35
At Elkton				
Interstate Commission	(Elkton)	9.2*	11.6	6.2
Va. Water Control Bd.	S-2	9.0**	12.8	6.0
PHS	S-12	8.05***	8.70	7.3
Below Elkton				
Interstate Commission	171-131	8.5*	13.1	5.3
PHS	S-13	7.35***	8.60	6.15
Above Front Royal				
Interstate Commission	171-56	7.6****	10.2	5.0
PHS	S-19	8.10***	10.25	7.65
Below Front Royal				
Interstate Commission	171-54	6.8****	10.0	1.4
Va. Water Control Bd.	S-4	11.2**	15.0	8.0
PHS	S-20	8.70***	10.55	7.40

*20 samples
**9 samples
***7 samples
****8 samples

At times of low flow there appears to be at least three points on the North Fork where D.O. depletions would be the most pronounced. According to Figure 48, the points of lowest D.O. would occur downstream from Timberville, Mount Jackson, and Strasburg.

The Main Stem of the Shenandoah River and Potomac River contained coliform organisms in excess of Class C water quality objectives at all sampling points as noted in Figure 47. The survey average BOD_5 in parts per million in these waters were within specified limits. On a poundage basis, Shenandoah River waters carried extremely large total BOD_5 loads. The BOD_5 entering the Potomac River from the Shenandoah River ranged to nearly one-half million population equivalents. Survey data indicate that about 40 per cent of the BOD_5 contained in Potomac River waters originate from the Shenandoah River.

According to 1958 PHS survey results, the section of the Shenandoah River from the Virginia - West Virginia border to the Potomac River contained tannin concentrations (0.95 ppm) and iron and manganese (0.75 ppm total) in excess of recommended limits for these constituents in domestic water (Potomac Report, Part III, December 1959, page 56).

The pH and alkalinity of Shenandoah Basin surface waters were generally within acceptable limits (see Appendix I).[1] However, the South River waters downstream from the textile plant (Station No. S-2) at Waynesboro contained color (ave. 22 units) in excess of that recommended for domestic water (recommend maximum of 20 units)[2] and Hawksbill Creek, downstream from the tannery at Luray, Virginia, (Sta. No. S-15) contained color ranging from 7 to 34 units. Color from these sources persisted for only short distances downstream.

All composite samples contained inorganic nitrogen concentrations in excess of the 0.3 ppm reported to be associated with nuisance algal stimulation (see Appendix II). At all composite sampling points the total solids were within suitable limits for domestic water use; that is, total solids were less than 500 ppm (PHS Drinking Water Standards) in all samples analyzed (see App. II).

The ratio of ultimate biochemical oxygen demand (L) to chemical oxygen demand (COD) was found to decrease markedly between upstream and downstream composite sampling stations. The L/COD ratios for composite sampling stations are shown in Table 30.

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[1] Public Health Service, Manual of Recommended Water Sanitation Practice, no. 525, (1946).

[2] Public Health Service, Drinking Water Standards, vol. 61, no. 11, (1956).

Table 30

Shenandoah River Basin
BOD and COD Relationships at Composite Sampling Stations

Sta. No.	Location	BOD_L lbs./day	COD lbs./day	Ratio $_L$/COD
S-1	Above Waynesboro	1,300	3,520	0.37
S-3	Below Waynesboro	4,060	12,700	0.32
S-11	Above Merck & Co.	12,080	40,000	0.30
S-12	Below Merck & Co.	23,630	74,500	0.31
S-19	Above Front Royal	15,070	133,800	0.11
S-20	Below Front Royal	23,500	164,700	0.14
M-4	Harpers Ferry	37,900	192,300	0.20

Since the COD determination is a measure of oxidizable carbonaceous organic material, the smaller ratios shown for Stations S-19, S-20, and M-4 in Table 30 indicate the possibility that BOD inhibiting materials exist in these streams waters.

The daily BOD series data on which ultimate BOD contents and deoxygenation velocity constants (k_1) for stream assimilative capacity determinations are based, are shown in Appendix II.

Biological Studies

A biological reconnaissance of a river can yield important information in addition to that obtained by chemical and physical determinations. Such studies can reveal the gross effects of long-time exposure of pollution on the aquatic environment and can better describe the productivity or non-productivity of the stream.

Generally polluted or unpolluted waters can be differentiated biologically by the types or kinds of organisms present in each situation. The almost universal existence of "pollution tolerant" and "pollution sensitive" organisms makes this differentiation possible. Basically, the type of respiratory system associated with various species of organisms is the dominant factor in determining by the presence or absence of organisms, the condition of the environment. In not all instances, however, does the absence of a particular "pollution sensitive" organism or organisms indicate pollution. For instance, consideration must be given to the productive nature of the stream bottom or substrate and to the possibility that by natural causes the food chain may have been broken.

The "pollution tolerant" types of organisms observed in the Shenandoah Basin streams were physid snails and tubificid worms. The "clean water association" of animals were mayfly nymphs, stonefly nymphs, damselfly nymphs, caddisfly larvae, operculate snails, hellgrammites, and crayfish.

Biological Sampling Results

South Fork - South River

Station S-1. This station is located upstream from all waste sources at Waynesboro, Virginia. The river widens to nearly 40 feet at this point and at the time of sampling varied from 18" to 36" in depth across stream. A dense growth of brush extended well out over the water from the high bank along the west shoreline. There were abundant growths of *Anacharis* or *Elodea* and *Typha* (cattails) in the stream along the east shoreline.

An Eckman dredge was operated at quarter points and mid-point across the river. The river bottom, at the west quarter point, was composed of silt, coarse sand, and gravel. No organisms were found in the dredge haul. At mid-stream, small rocks made it impossible to sample with the dredge. Coarse sand, gravel, silt, small rocks, and organic detritus comprised the bottom materials at the east quarter point. No aquatic organisms were observed in the dredge haul. There was no noticeable septic odor present in the dredge samples.

Five sweeps with a BV dip net among the aquatic vegetation yielded several dragonfly nymphs.

It appeared that this section of the river may at times act as a settling basin for sand, silt, and organic detritus coming from upstream. This may be a partial explanation for the scarcity of aquatic bottom organisms.

Findings at this station showed the stream to be in good condition, although the bottom substrate was not of a particularly productive nature.

Station S-1A. The river continued wide at this location and was shallow enough to be waded out to mid-stream. The bottom was extremely rocky over a substrate of coarse sand and gravel. Algal and bacterial slimes formed dense growths over the rocks.

The condition of the stream was considered to be good in this area.

Station S-1B. This riffle area located upstream from sources of waste was characterized by rocks of almost every size and description. The rocks extended across the entire stream bed over a substrate of sand and silt-like material, and were well covered with algal and bacterial slimes.

Caddisworms (larvae) were the dominant insect group and were present in great abundance. Operculate (gill breathing) snails existed on the rocks by the hundreds. Mayfly larvae and water pennies were also found in great abundance.

Observations at this station showed the stream to be in good condition from the aquatic ogranisms standpoint.

Station S-2. This station is located about 500 yards downstream from industrial waste sources at Waynesboro, Virginia. The river is divided into two channels at this point; one channel appearing to carry wastes discharged along the west bank and the other wastes discharged along the east bank. Water in the west channel was reddish-brown in color.

The river bottom was composed of many sizes of rocks covered by dense growths of Sphaerotilus. There appeared to be a considerable amount of suspended material in the water. The organisms present were physid snails (lung breathing) and tubificid or sludge worms.

From the standpoint of organisms and growths found, the stream was in poor condition at this station.

Station S-2A. This station, a rocky riffle area, is located at the C&O Railroad crossing several hundred yards downstream from Station S-2.

The stream water had a reddish-brown cast which was enhanced by the reflection of colored material deposited on the river bottom.

There was an oily septic sludge deposit two feet deep at the downstream edge of the bridge pier. Sphaerotilus covered the rocks and clumps of this growth were seen floating downstream. The animal life was relatively sparce at this station and only a few leeches and physid snails could be found.

From the biological standpoint the stream was in very poor condition at this sampling station.

Station S-3A. This station is about 4.5 miles downstream from municipal and industrial waste sources at Waynesboro. Many rocks were observed along the east shoreline and the river bottom was composed of clean stone and coarse gravel. The rocks were well covered with mosses and algae, and a few rooted higher aquatic plants were observed growing along the banks.

Physid snails were the dominant animals and many hundreds of snail egg masses were observed. Snail-eating leeches and membranous tube-forming caddisworms were also present.

From the standpoint of aquatic organisms found the stream at this sampling station was in good condition.

Station S-4A. This sampling station is about 25 river miles downstream from waste sources at Waynesboro. It is identified by a rocky spit along the east shore extending about one-fourth of the way across the river. The rocks varied from golf ball to boulder size. Algal and diatomaceous slimes covered the rocks.

Gyrinid or Whirligig bettles were noted darting across the surface of the water, and many schools of minnows with 50-100 fish per school were seen. The following animals were well represented: damselfly nymphs, mayfly nymphs, haplid beetles, caddisfly larvae (both the web building and store building), dragonfly nymphs, hellgrammites, stonefly nymphs, planarian, water pennies, many operculate snails, and a few physid snails. Rooted aquatic weeds grew in abundance in the marginal areas.

Although heavily polluted at Waynesboro, the South River, with many riffle and pool areas providing a high degree of waste treatment, displayed exceptional recovery before joining the North River near Grottoes.

South Fork - Middle River - Lewis Creek

Station S-5. This station, located downstream from waste discharges at Staunton, Virginia, was heavily polluted with domestic waste. The river bottom is composed largely of sand and gravel which is a relatively non-productive substrate even without outside interference. Upon probing this sand and gravel material black odorous organic material was revealed. Leeches and chironomid larvae (bloodworms) were abundant in this material.

Small rocks covered with zoogleal slime and blue-green algae were scattered over the sand and gravel substrate. Sludge deposits with filamentous green algae growing over them existed mostly along the south shoreline. Tubificid worms living in and on this organic material formed a colony about 2 feet wide and 14 feet long. A few minnows were observed swimming about.

From the biological standpoint, the stream was in very poor condition at this sampling point.

South Fork

Station S-11. This station is located about two miles downstream from the confluence of the North and South Rivers. Examinations were made of a rocky spit extending into the river from the east bank. The rocks, golf ball to boulder size, were well covered with algal, diatomaceous, and bacterial slimes. A good assemblage of aquatic animals were present, including: caddisfly larvae, cap snails, physid snails, hellgrammites, stonefly nymphs, water pennies, water striders, and mayfly nymphs. Many centrarchid (black basses, crappies, and sunfish) nests were observed hollowed out in the silt among the rocks. Broad leafed rooted aquatic plants were very much in evidence along the margin of the river.

All observations indicated the stream at this sampling station to be in very good condition.

Station S-12A. This station is located at Elkton, Virginia, downstream from Merck and Company. The river at this point makes a bend to the left looking upstream, and the sampling was done along a rocky shelf which follows this bend in the river. The main channel was too deep to wade and the velocity was past the scouring stage.

Stonefly nymphs, caddisfly larvae, and mayfly nymphs were abundant in the rocks. Crayfish, planarian, physid snails, cap snails, and minnows were also found. Sunfish were present as indicated by the catch of several fishermen.

From the standpoint of aquatic organisms found, the stream at this sampling station was in good condition.

Station S-13A. This station is identified by a stone spit extending out into the river just below the tailrace of the power dam at Shenandoah, Virginia.

The aquatic organisms present were: mayfly nymphs, caddisfly larvae, cap snails, haplid beetles, planarian, gyrinid beetles, leeches, schools of minnows, and physid snails and their egg masses. Fish were seen jumping out in mid-stream.

Luxuriant growths of rooted aquatic plants were observed along the east bank. Fishing was reported good in this area.

From observations made, the stream appeared to be in good condition.

South Fork - Hawksbill Creek

Station S-14A. This station is located upstream from the waste outfalls at Virginia Oaks Tannery and Luray, Virginia. The river bottom was composed of stones and rocky ledges, and the water was from one to two feet deep.

Hundreds of operculate snails were observed clinging to the rocks. The underside of the rocks contained mayfly nymphs, caddisfly larvae, stonefly nymphs, hellgrammites, planarian, crayfish, leeches, and aquatic sow-bugs. Many schools of minnows were observed swimming throughout the area.

The condition of the stream, from the standpoint of aquatic organisms found, was considered very good.

Station S-15. This station is located downstream from the points at which wastes from the Virginia Oaks Tannery and Luray sewage treatment plant are received in the stream. The river bottom is composed of various sized rocks scattered over a sandy substrate.

There was a heavy growth of the alga Hydrodictyon (water net) on the rocks. Streamers of this alga up to 15 feet long were observed. The underside of rocks teemed with aquatic organisms. The aquatic sow-bug was the dominant organism, and next in abundance was the mayfly nymph. Planarian, caddisfly larvae, hellgrammites, physid snails, cap snails, crayfish, and minnows were also plentiful. Many centrachid (black basses, crappies, and sunfish) nests were observed over the river bottom.

At this station the river varied from 12 to about 20 inches in depth and appeared reddish-brown in color. However, upon examination with the Secci disc, the water was clear indicating that the colored appearance was due to reddish-brown colorations on the stream bottom.

From all appearances, the stream at this sampling station was in good condition.

North Fork

Station N-1. This station is located upstream from all waste sources. The stream bottom is composed of rocks and the cross depth of the stream varied from several inches to about 2.5 feet.

Operculate snails were visible everywhere and caddisworms existed in great abundance. Extremely large stonefly nymphs, mayfly nymphs, damselfly nymphs, hellgrammites, physid snails, haplid beetles, gyrinid beetles and water pennies were also extremely abundant. Hundreds of minnows were seen moving in every direction. It was reported that three large rainbow trout had been taken from the river several hundred yards upstream from this station.

In view of the type habitat and organisms found, the condition of the stream at this sampling point was considered excellent.

Station N-2A. Samplings were performed around an island which separates the river into two channels, well downstream from waste sources in the Broadway-Timberville area. The river bottom was made up of rocks, small twigs, and tree branches spread over a coarse sand substrate. All rocks were well covered with algal and diatomaceous slimes. There also were growths of filamentous algae on the rocks, on small twigs, and on tree branches.

Along the south bank of the island there was a deposit of organic material several inches deep. This material was composed of leaves, twigs, and other organic material; a strong septic odor was present when the material was disturbed.

Numerous mayfly nymphs, stonefly nymphs, leeches, and caddisfly larvae were observed living among the rocks; centrarchid (black basses, crappies, and sunfish) nests were also observed.

Except for the deposit of septic organic material, the condition of the stream from the standpoint of organisms present was good.

Station N-5. This station is located downstream from Strasburg, Virginia. Sampling was performed along a sand and gravel shoal that extended 15 to 20 feet from the south bank, and along a rocky riffle area over a sand and gravel substrate which extended 25 to 30 feet beyond the shoal. The rocks were partially covered with algal growths, and rooted aquatic plants grew luxuriantly in the shallower marginal areas.

Contrary to usual habitats, mayfly nymphs, stonefly nymphs, caddisfly larvae, and damselfly nymphs were prospering in silt deposits among the rocks. Planarian and operculate snails were also fairly common; however, no minnow schools were observed.

Examination was made of a quiescent backwater pool located approximately 15 yards upstream from the sampling area. The bottom of the pool was composed of mud and organic debris. Upon disturbing this material, a pronounced septic odor was produced.

From the standpoint of aquatic organisms found, the stream at this sampling point was in good condition. The oxygen demanding organic material found in the pool indicated that sources of significant amounts of such material exist upstream.

Shenandoah River - Main Stem

Station M-1. This station is located below the confluence of the North and South Forks and is downstream from waste sources at Front Royal, Virginia.

Rocks of every size and description lined the banks on both sides of the river. Numerous aquatic animals were found among the rocks and were of kinds expected to live in relatively unpolluted water. The animals were: hellgrammites, damselfly nymphs, mayfly nymphs, caddisfly larvae, stonefly nymphs, water pennies, and planarian.

During the May - June 1960 survey the only biological sampling station to reveal significant numbers of free-floating plankton was Station S-13 located downstream from the power pool at Shenandoah, Virginia. It is believed that the absences of planktonic forms at most stations, rather than being attributable to a lack of nutrient material or presence of toxic waste components, resulted from unsuitable flow velocities, turbulences, and accompanying turbidities encountered during the survey period.

DISCUSSION OF STREAM SURVEY RESULTS

WATER QUALITY AND EFFECT OF WASTES

The stream sampling data collected during the 1960 field survey has provided a means of defining the general water quality in the Shenandoah Basin and has pointed out several stream sections significantly affected by wastes. The waters of highest quality existed in stream reaches receiving no municipal or industrial wastes, or at locations downstream from waste sources where recovery or improvement in quality by natural self-purification processes had taken place.

Water of a quality suitable for water supply purposes was found to be essentially a function of quantity and types of wastes received and rate of natural self-purification and dilution in the various streams. The parameters examined, other than coliform group organisms, biochemical oxygen demand, dissolved oxygen, and phenolic compound (tannin and lignin), were generally within concentration limits suitable for raw water supplies, although it is known that at times of flash runoff the turbidity and solids contents exceed desirable limits for removal of these substances by conventional water treatment methods.

Although not the only factor incident to nuisance algal blooms, the inorganic nitrogen concentrations found could be expected to influence nuisance blooms of algae and perhaps nuisance weed growths in almost any possible stream impoundment area.

Since the numbers of coliform organisms in most waters appear to be the greatest single offender of water quality, it is apparent that chlorination of sewage effluents would provide significant improvements for protection of the health of downstream water users.

The sampling results and biological studies reveal several stream reaches where fish and other aquatic life are or may be adversely affected by large waste loads during low flow periods. Municipal and poultry processing wastes received in Blacks Run from Harrisonburg, Virginia, constitute a hazard to public health and to stream life in the North River, especially when combined with wastes from Bridgewater, Virginia. The Middle River is subject to damaging waste loads from the Staunton-Verona area. The extremely poor condition of Lewis Creek to which Staunton wastes are discharged exemplifies the condition that may be found in the Middle River downstream from Lewis Creek during sustained low flow periods. However, secondary treatment of wastes at Staunton should greatly alleviate the possibility of such a condition taking place.

The South River below Waynesboro, Virginia, is essentially useless for any purposes other than for disposal of wastes. Despite the relatively high degree of municipal and industrial waste treatment at Waynesboro, the low flows in the South River are not great enough to prevent serious damage to the stream.

The South Fork, downstream from Merck and Company, Inc., and Elkton, Virginia, is subject to significant dissolved oxygen depletions during sustained low flow periods. The power pool at Shenandoah, Virginia, is especially endangered with respect to oxygen depletion. Treatment facilities at Merck are exceptionally good, but effluents contain considerably high waste loads in relation to minimum stream flows that have occurred in the South Fork. It would appear that all of the stream flow in this area is required for dilution and assimilation of wastes, and none should be taken for water supply.

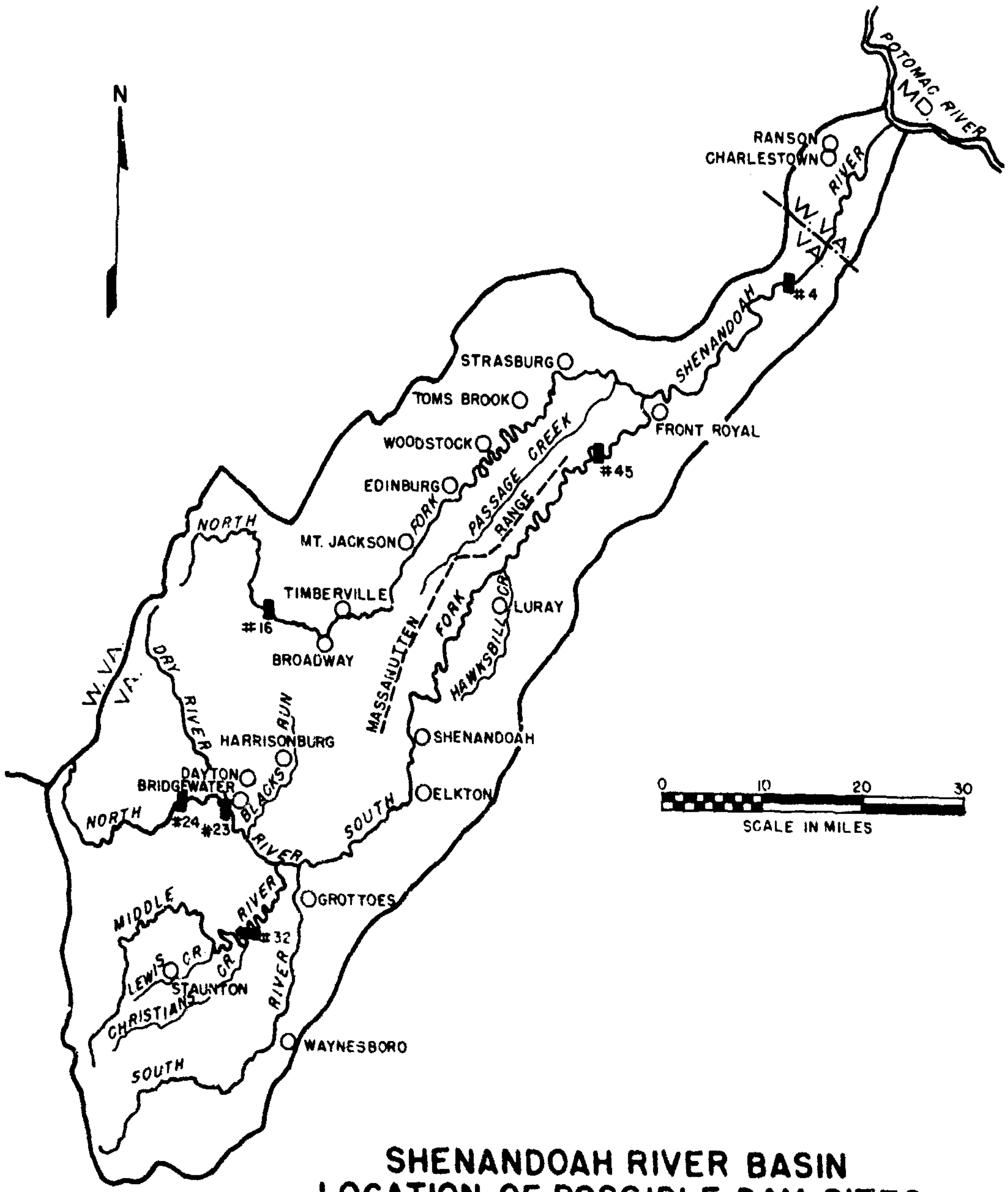
The data have shown that, on occasion, waters of the South Fork upstream from Front Royal have contained relatively low dissolved oxygen concentrations (5.0 ppm). On such occasions, the added oxygen demand by wastes received from Front Royal have resulted in extreme low dissolved oxygen concentrations downstream (1.4 ppm D.O. at 600 cfs flow). The need for control measures to prevent recurrence of this condition appears warranted.

Under sustained low flow conditions the North Fork Shenandoah is subject to significant dissolved oxygen depletions downstream from Timberville, Mt. Jackson, and Strasburg, Virginia. Although exceptionally high treatment efficiencies are accomplished on packing house, poultry processing, and cannery wastes in the Broadway-Timberville area, the total waste load, including seasonal waste loads from cannery operations (low flow time of year), produces a large total waste load in relation to flows that have existed during low flow periods. The possibilities of critical D.O. depletions below Mt. Jackson and Strasburg could be alleviated by waste treatment at all communities along this section of the North Fork.

The status of water quality in the Main Stem of the Shenandoah River is dependent mainly upon municipal, industrial, and agricultural activities taking place on the North and South Forks. Although the Shenandoah River carries thousands of pounds of BOD and solids per day, the volume of flow and stream characteristics affecting reoxygenation prevent any serious degradation of water quality. Should it be that BOD inhibiting materials exist in these waters, the effect is only to further prevent serious depletions of dissolved oxygen. However, upon dilution of Shenandoah River waters with Potomac River waters, these inhibitive properties may become reduced, thus releasing latent BOD for action downstream and in the Potomac Estuary. This effect may also explain the unknown source of increased BOD_5 found between Whites Ferry and Great Falls during the 1958 survey (Potomac Report, Part III, December 1959, page 6).

WATER QUALITY AND SANITATION RELATIVE TO POSSIBLE RESERVOIR SITES

The Corps of Engineers has six possible reservoir sites in the Shenandoah Basin under investigation. Figure 51 shows the approximate location of these sites.



SHENANDOAH RIVER BASIN
LOCATION OF POSSIBLE DAM SITES

FIGURE 51

Shenandoah River, South Fork - North River

Sites No. 23 and No. 24

Stream waters relative to these two sites on the North River are of excellent quality and no significant waste sources exist upstream. Either of the proposed reservoirs would be readily accessible for use as a source of raw water supply to the Harrisonburg - Bridgewater - Dayton and surrounding Rockingham County, Virginia, areas.

Present sources of water serving the area consist mainly of springs. With the continuation in rate of increased water use experienced in recent years, these sources could not be expected to supply all future needs. Alternate dependable sources of water in the area are limited and treatment to reduce hardness of these waters is required before use. Water supply storage and stream flow regulation on the North River would therefore be a great asset to the future development of the Rockingham County area.

Improved stream quality resulting from low flow increases from either of these proposed reservoirs would accrue in the Bridgewater - Dayton - Mt. Crawford reach of the North River and downstream from the mouth of Blacks Run to which Harrisonburg wastes and treatment plant effluents are discharged.

Assured increases in low flow from either of the North River reservoirs would also improve the quality of the South Fork by diluting and assimilating impurities and nutrient materials received in the Middle River from Staunton, Virginia, and in the South River from Waynesboro, Virginia. Increased low flows to the South Fork would in turn reduce the concentrations and assimilate municipal and industrial waste components received at Elkton, Shenandoah, Luray, and Front Royal.

Increased low flows from the Shenandoah River resulting from either of these impoundments would improve the quality of Potomac River water and increase the quantity available for water supply at Washington, D. C., during low flow periods.

Shenandoah River, South Fork - Middle River

Site No. 22

The stream water at this site is contaminated by sewage and industrial waste effluents from the Staunton and Verona area. Although most of these waste effluents undergo partial assimilation in Lewis Creek (small amount in Christian Creek and the Middle River) before entering the headwater areas of the proposed reservoir, the degree of treatment applied (primary treatment) does not yield an effluent of sufficient quality to result in safe use of water from

all points in the reservoir for municipal supply. However, plans have been completed at Staunton for construction of a new sewage treatment plant which will more effectively reduce the objectionable constituents contained in these wastes. Further stabilization in Lewis Creek prior to entering the reservoir, together with additional stabilization and dilution within the reservoir would render waters at a point immediately above the dam or at a point in another arm of the reservoir suitable as a source of raw water for municipal purposes.

However, extreme caution should be applied to safeguard municipal uses of water from this reservoir. With sewage effluents entering the reservoir from Lewis Creek, Christian Creek, and the Middle River, together with minimal tributary dilution flows during low flow periods, a used water recycling situation could be produced.

The following incident is presented to show that continued recycling of used waters in storage can result in waters of unacceptable potability and hazards to public health.

At Chanute, Kansas, the emergency recycling of treated sewage (approximately 1.5 MGD) for water supply in a 20 million gallon pond (20 day recycling period) produced water of very low physical and chemical quality. Within the five month recycling period the finished water became pale yellow in color, frothy from detergent build-up, and had an unpleasant musty taste and odor. The raw water became increasingly difficult to coagulate and settle by treatment and taste and odor control by chlorination was virtually impossible because of the high nitrogen content.[1]

The build-up of minerals contributing to hardness of recycled water became so great that considerable carry-over of floc occurred in the softening process. The chloride content alone increased from 40 milligrams per liter (mg/l) to 400-500 mg/l, and sodium increased from the normal of 30-60 mg/l to 380 mg/l which is of significance to persons having cardiac ailments.[2]

Coliform organisms in the pond water at Chanute were lower than usually found in the river water because of the high degree of sewage treatment applied and stabilization in storage. Algal forms were very abundant even in January and February when pond water temperatures were about 42°F. The sewage at Chanute contained low concentrations of Endameba histolytica and other parasitic protozoa, but none were found in the treated water. However, cysts of free living amoebas (non-pathogenic) similar in size to the Endameba histolytica were found regularly in the treated water indicating low treatment plant efficiency in removing such organisms.[3]

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[1] D. F. Metzler, et al., "Emergency Use of Reclaimed Water for Potable Supply at Chanute, Kansas," Jour. of Amer. Water Works Assoc., vol. 50, (August, 1958).

[2] Ibid.

[3] Ibid.

The recycling of sewage treatment plant effluents for water supply at Chanute, Kansas, is perhaps an extreme case. With rapid and extensive development in the Staunton and Verona area, effects of perhaps lesser total magnitude, but with similar hazards could be produced and therefore should be recognized.

As a result of stabilized nutrient products produced during the process of waste stabilization, there would be times when the waters at the deeper levels of the proposed Middle River Reservoir would contain low dissolved oxygen concentrations; surface and shallow areas would contain nuisance plant growths and algal blooms.

The reservoir would offer a source of water for industrial purposes and for sanitary district and municipal use in the event that sources less susceptible to sewage contamination cannot be developed. The reservoir would serve as a source of water to the following areas: Staunton - Verona, Waynesboro, the area between Staunton and Waynesboro, and the South River sanitary district which includes Stuarts Draft, Virginia. Spring-fed streams and small creek impoundments presently serve as the source of municipal and industrial water for these areas. Perhaps these sources should be reserved only for municipal and domestic use by sanitary districts until such time as it would become necessary to use the less safe water from the proposed Middle River Reservoir.

In the absence of substantial water storage development, the increasing demands and anticipated future municipal and industrial growth in the "Three Rivers" area will require development of many additional small impoundments. A large water supply impoundment such as proposed for the Middle River would be a great asset, especially to the Augusta County, Virginia, area.

In addition to stabilizing residual waste material from the Staunton - Verona area, increased low flow regulation from this reservoir would result in improved water quality in the South Fork at Elkton, Shenandoah, Luray, and Front Royal.

Increased low flows from the Shenandoah River, resulting from an impoundment on the Middle River, would improve the quality of Potomac River water during low flow periods and would benefit the water supply at Washington, D. C. by improving the quality and increasing the minimum available quantity.

Shenandoah River, South Fork

Site No. 45

The stream waters at this site contain residual municipal waste constituents from seven upstream communities (total population - 55,000), and residual industrial waste constituents from four major water-using industries. Stream sampling results show that despite

partial stream assimilation of municipal and industrial wastes in various upstream reaches of the South Fork, additional off-setting BOD loads contained in agricultural and natural land runoff result in a combined daily average load to the proposed reservoir area equivalent to a sewage BOD_5 load from a population of approximately 90,000 persons. Stream sampling results also show that the waters entering the reservoir area contain significant concentrations of aquatic plant nutrients and occasionally contain coliform group organisms in excess of maximum numbers usually recommended for raw water supplies requiring complete conventional treatment.

The reservoir, while not being situated in a water deficient area and therefore possessing no local water quantity benefits, would provide a medium for stabilization and sedimentation of residual wastes and runoff material entering from upstream. Waters thus stabilized and clarified would be of improved quality for municipal and industrial water supply use at Front Royal, Virginia. In stabilizing wastes contained in the in-flowing waters, the water at the deeper levels of the reservoir, because of restricted atmospheric reaeration, would contain low dissolved oxygen concentrations. Algal blooms and weed growths would be stimulated in surface and shallow areas, and the bottom would be subject to considerable depositing of silt. In view of the occurrence of relatively large numbers of coliform organisms, the use of the proposed reservoir for recreational purposes would constitute a potential health hazard to such users. Insofar as the new use would have been created by the project, it is entirely possible that costs for protection of that use might be chargeable to the project.

Regulated increases in low flow with water released from levels not significantly reduced in D.O. content would improve quality of water in the South Fork and in the Shenandoah River downstream from municipal and industrial waste discharges at Front Royal.

The improved quality and increased minimum flow of the Shenandoah River resulting from this impoundment would be of benefit to the water supply at Washington, D. C., by improving the quality and increasing the minimum quantity of water available from the Potomac River in that area.

Shenandoah River, North Fork

Site No. 16

Water at this site is of excellent quality and no significant waste sources exist upstream. The site is immediately accessible for use as a source of raw water supply in the Broadway - Timberville, Virginia, area.

Because of limitations in summertime yields of the well and spring water, and exceedingly low drought flows in the North Fork, an

impoundment would be extremely beneficial to this area as a means of satisfying future water demands. This reservoir could also serve the water supply needs in the Harrisonburg - Bridgewater - Dayton area.

Water storage and stream flow regulation to provide assured minimum flow increases in the North Fork from this site would be a great asset to the future development of a large portion of Rockingham County, Virginia. It would also provide greater assurance to the city of Winchester and surrounding Frederick County area that future diversions of water upstream from their intake, located near Strasburg, would not create shortages.

Low flow regulation from this proposed reservoir would provide water quality improvements downstream in the North Fork at Broadway, Timberville, New Market, Mt. Jackson, Edinburg, Woodstock, and Strasburg, Virginia, and in the Shenandoah River downstream from Front Royal. The improved quality and increased quantity of water from the Shenandoah River resulting from this impoundment would be of benefit to the water supply at Washington, D. C., by improving the quality and increasing the minimum quantity available from the Potomac River in that area.

Shenandoah River

Site No. 4

The stream waters at this site contain residual municipal waste constituents from 23 upstream communities (total population 80,000) and residual industrial waste constituents from 7 major water-using industries. Stream sampling results show that despite various degrees of waste treatment at the sources and stream assimilation of these wastes throughout various reaches of upstream tributaries and sub-tributaries, additional off-setting BOD loads contained in agricultural and natural land runoff result in a combined daily average load to this proposed reservoir area equivalent to a sewage BOD_5 load from a population of approximately 180,000 persons. Stream sampling results also show that the waters entering the reservoir area contain significant concentrations of aquatic plant nutrients and numbers of coliform organisms in excess of maximum numbers usually recommended for municipal raw water supplies.

The reservoir, while not being situated in a water deficient area and therefore possessing no local water supply benefits, would provide a medium for stabilization and sedimentation of residual wastes and runoff materials entering from upstream. In stabilizing and clarifying these waters, low dissolved oxygen concentrations would exist at deep water levels, algal blooms and weed growths would be stimulated in surface and shallow areas, and the bottom would be subject to considerable depositing of silt. In view of the occurrence of relatively large numbers of coliform organisms, the use of the reservoir for recreation would constitute a potential

health hazard to such users. Insofar as the new use would have been created by the project, it is entirely possible that costs for protection of the new use would be chargeable to the project.

Controlled increases in minimum low flow by releases of water from levels not significantly reduced in D.O. content would provide greater capacity for assimilation of wastes received in the Shenandoah River from the Charles Town - Ranson - Halltown area and would provide significant improvement in the quality of Potomac River water downstream from the mouth of the Shenandoah River.

Stream sampling results show that approximately 40 per cent of the oxygen demanding materials carried in the Potomac River below the mouth of the Shenandoah River originate from the Shenandoah River. On the basis of this and other factors associated with impoundment stabilization characteristics, it is evident that this proposed reservoir with releases designed to utilize maximum dissolved oxygen resources, along with increased minimum stream flow, would provide substantial improvements in the quality of Potomac River water for water supply at Washington, D. C., and would benefit the supply by increasing the minimum available quantity.

CRITERIA FOR DETERMINING PROJECTED WATER REQUIREMENTS FOR WATER SUPPLY AND POLLUTION ABATEMENT IN THE POTOMAC RIVER BASIN

GENERAL

The protection of public health through the provision of a safe water supply has long been a matter of primary concern to the public health profession and has been a significant contributing factor to the high health standards of the Nation. However, the problem of providing adequate amounts of safe potable water has become increasingly difficult due to the pyramiding water demands of a rapidly expanding population. Furthermore, the resulting increase in waste flows has caused a gradual degradation in the quality of the Nation's waters. While improved methods of treatment and disinfection of both wastes and water have served to maintain the quality within tolerable limits, the progress in pollution abatement and water treatment has not kept pace with this population growth and industrial expansion.

The familiar problems of pollution by bacteria, organic matter, and chemicals of known toxicity and behavior have been further intensified and complicated by problems of mineral enrichment due to water re-use and by new types of contaminants associated with our chemical and atomic age. The effects of these newer contaminants on water treatment processes and on the human consumer are largely unknown. The deficiencies in knowledge and the prospect of even greater quantities of yet more complex pollutional materials reaching our surface waters emphasize the urgency of intelligent water quality management.

It is recognized that water for human consumption holds the highest priority of all water uses. The increased demands on quantity by an increasing variety of uses has also brought about many conflicts which can be solved only by intelligent and long-range management practices. Unfortunately, practically every water use results in some degradation of quality. As the supply becomes more critical and conflicts in use increase, water quality is assuming increasing importance.

Where alternate sources are available it is desirable to reserve the highest quality water available for domestic use and to satisfy other lower priority demands with waters of lesser quality. In areas of limited supply the ultimate water requirements can be met only by water re-use. Thus, dependence must be placed upon improved and more effective methods of water and waste treatment in order to maintain the highest possible standards of quality for human consumption. However, in such instances every effort should still be made to reserve a sufficient quantity of high quality natural waters for domestic use before they flow on to supply other less critical demands.

It is sound planning to utilize highest quality water for highest priority uses, and the protection of this quality against irreversible and potentially hazardous degradation must be practiced to the fullest extent possible.

The magnitude of increased water use for all major purposes in the United States during the 55 year period 1900-1955 was from 40.2 billion gallons to 263.8 billion gallons per day.[1] The development of American agriculture, industry, rural life, and metropolitan growth has been based primarily upon the availability of an abundant and economical water supply of suitable quality. By 1980, water use in the United States for all major purposes is expected to be 494.1 bgd, or an increase of 230.3 bgd from 1955. Table 31 shows the water uses by categories as estimated for the United States.

Studies made on public water supplies indicate that there were about 4,000 supplies serving 30 million people in the year 1900; 17,500 supplies serving an estimated 111 million people in 1955; and by 1980 it is expected that 167 million people will be served by public water supplies in the United States. Such supplies furnish water for domestic, commercial, and industrial purposes within their areas of distribution. The studies on water use incorporated surveys made by the American Water Works Association, the U. S. Public Health Service, and the Water and Sewerage Industry and Utilities Division of the Business and Defense Service Administration, U. S. Department

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[1] W. L. Picton, "Water Use in the United States, 1900-1980," Business Service Bulletin, Department of Commerce, (March, 1960).

of Commerce. From these sources of information on water uses and Census Bureau figures on populations it is found that in addition to increased water demands by direct increases in population, the per capita daily average use of water in the United States in on the increase. National municipal per capita water use in 1958 was about 150 gallons per day (gpd). In view of past trends it is reported that the per capita daily average municipal use is expected to average 192 gpd by 1980.[1]

Table 31

Water Use in the United States
1900-1980 - U. S. Department of Commerce

Use Category	Billion Gallons Per Day - Average 1900	1955	1980
Irrigation	20.2	116.3	178.0
Rural	2.0	5.4	7.4
Public	3.0	16.3	32.0
Industrial & Miscellaneous	10.0	49.2	115.0
Steam-Electric	5.0	76.6	161.7
All Uses	40.2	263.8	494.1

From a study of 58 municipal systems operated by the American Water Works Service Company, Inc., it was revealed that residential sales of water per service for the years 1939-1956 increased fairly uniformly at the rate of about 2 per cent per year.[2] It was also indicated that metered residential sales increased with rising family income. Although data on peak demands were incomplete, available data indicate that maximum daily demands attributed to lawn sprinkling, air conditioning, and refrigeration resulted in demands ranging from 139 to 177 per cent of the typical weekday use. These peak demand rates correspond to additional rates of 140-277 gpcd (gallons per capita per day).[3] The available data showed that the relationship between maximum and average day demands during the period 1939-1956 remained constant.

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[1] Ibid.

[2] The Task Committee, American Water Works Association, "Study of Domestic Water Use," Jour. of Amer. Water Works Assoc., (November, 1958).

[3] Ibid.

CRITERIA FOR DETERMINING FUTURE MUNICIPAL AND SANITARY DISTRICT WATER REQUIREMENTS

Because provision of a continuously adequate and potable water supply is basic to public health and the general well-being of the populations and economy, planning for future water demands and uses requires the utmost of care and application of a reasonable degree of optimism. This is especially true when planning for requirements 50 years in advance or to the year 2010 as is the objective of this evaluation.

The municipal or public water supply system referred to in this investigation is defined as that facility serving all urban and sub-urban populations and commercial or small industrial users located within areas of reasonable distribution. A sanitary district water supply system is defined as that facility which serves or may serve unincorporated small town populations, commercial or small industrial users outside of municipal limits, and rural non-farm populations located within areas of reasonable distribution from the facility.

Water requirements for municipal and district uses are given by areas within the drainage basin as governed by centers of population and location with respect to possible reservoir storage sites. Requirements within each area are determined from county population figures projected to the year 2010 by the Office of Business Economics, Department of Commerce. Since not all county populations would be served by central water supplies, a division is made into those populations expected to be served by municipal and district supplies, and those expected to have individual supplies. The municipal and sanitary district population figures are then multiplied by an appropriate daily per capita water use figure to obtain the total requirement (see Rationale, page 361). In event that water storage is required, both daily average and maximum daily average water requirements are given for use in determining reservoir storage capacity; that is, the former value for supplies taken directly from storage and the latter for supplies taken downstream.

Based on studies of per capita water uses and apparent trends toward increased per capita demands in the future, the added annual unit increase in daily per capita municipal and district water uses is taken as 1.5 per cent of the 1960 per capita figure. Maximum daily uses are obtained by adding 50 per cent of the 1960 average gpcd as a constant to the future increases in average gpcd.

The county populations provided by the Office of Business Economics are divided into two categories; namely, farm and non-farm populations. The non-farm populations are further divided into three groups: rural residential, small town, and urban. Municipal and district water requirement evaluations concern mainly the non-farm population groups although it is known that farmers in certain areas haul significant amounts of water by tank truck from municipal

systems. Area water requirements for municipal and district purposes include all urban populations, up to 85 per cent of the rural residential populations by the year 2010 (75 per cent where sanitary districts do not presently exist) and certain small town populations which are expected to exceed 1,500 by the year 2010.

RATIONALE - MUNICIPAL WATER SUPPLY DEMAND

The demand for municipal water supply is created by a number of special uses; i.e., domestic, commercial, public, fire, and industrial. The number and diversity of commercial business establishments, attractiveness to tourists and conventions, community habits, public policy with respect to civic duties, and size and type of industries within any city are peculiar to that city under consideration, only. As a consequence, the municipal water demand computed on a per capita basis can be expected to vary among cities. Very often for purposes of developing over-all data on municipal water demand, writers have grouped cities by population brackets to determine unit water use. While this method furnishes a general idea of over-all quantity of municipal demand, an engineer developing estimates of future water needs of a specific city would look primarily to the characteristics of the city under consideration.

The rates of municipal water use are affected by the size of the community, its location, habits and standard of living, availability of water, quality and cost of the water, the existence of sewers, extent and use of meters, pressure maintained on the distribution system, and other variables.

It should be pointed out that municipal uses are largely nonconsumptive and it can be expected that about 90 per cent of the municipal demand will be returned to the water courses.

Domestic Use

The water used by the individual as a beverage is a very small quantity. The water used by the individual for such purposes as bathing, laundry, toilet, kitchen, automobile washing, and yard use are much larger demands for domestic purposes.

In projecting domestic water use, it is reasonable to believe that the standard of living will get progressively higher and that individuals will install water-using devices for convenience and comfort. Considering the use of existing water-using devices by apartment occupants only, a use of over 80 gpcd can be foreseen. For individuals occupying houses, a use of 110 gpcd can be expected.

Commercial Use

This water use is a composite of demands by many diversified business establishments such as hotels, motels, restaurants, shopping centers, bowling alleys, auto repair garages, auto service stations, and laundries. The type and number of such establishments will vary among communities and is dependent upon the population as well as many other considerations of community character. A city such as Washington, D. C., which attracts tourists, conventions, and other visitors would probably have a large water demand based on this consideration only. For instance, a restaurant will require about 9 gallons of water per meal served, and a motel or hotel will have a demand of 70 gallons of water per day per guest.*

Observations made by others show water uses from 10,000 gallons per acre per day for a shopping center to over 90,000 gallons per acre per day for a complex merchantile district of a large city.

Public Use

Water used for public purposes includes street washing, park fountains, lawn watering, public buildings, public schools, and public hospitals. The rate of use will vary in communities according to the character of the city and public policy reflecting degree of civic pride. This water is often supplied to the city without remuneration to the municipal waterworks.

Fire Protection

Protection against fire is an important function of a municipal waterworks. The total yearly quantity used for this purpose is small, but during a fire the rate of use is very great, making it necessary to have large volumes of water available to meet this emergency.

Industrial Use

This use varies greatly according to the nature of the manufacturing and each case must be studied individually. Observations made by others show that the industrial use may range from 0 to over 80 gpcd, based on the entire population of a city.

Waste

While wastage of water is not a use, it is certainly a consideration in developing a water supply adequate for the community, since such wastage would appear within the gross per capita demand figure. Waste results from leakage aggravated by high pressures on the distribution system and carelessness or unwillful neglect by users.

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* Thesis for Masters Degree - Phillip Searcy

Summary

In planning future water requirements for an area, it is believed that the prime consideration should be for public health and convenience. Estimates of future water requirements to meet all foreseeable needs should be generous. A rigid interpretation of historical records has in the past almost always resulted in an under-designed water system. In U. S. Senate Committee Print No. 7, page 11, of the Select Committee on National Water Resources, it was stated that the present 147 gpcd of average municipal use could conceivably increase to about 185 gpcd in 1980 and to 225 gpcd in the year 2000, with a possible leveling off thereafter.

It is believed that the best estimate of municipal demand can be developed by utilizing the historical record of each community and projecting increased use at a rate of 1.5 per cent per year. Existing variations of the several uses as previously discussed are already built into historical records. It is recognized that an upper limit of per capita water use will develop; beyond that limit, use might be considered wasteful. Based on present knowledge, this upper limit will probably be in the range of 225-250 gpcd. Estimates of future demand are tempered by this judgment factor.

CRITERIA FOR DETERMINING FUTURE INDUSTRIAL WATER REQUIREMENTS

Industrial water requirements are complicated by many factors affecting variability. Every product requiring water in its manufacture utilizes differing quantities and qualities of water and even identical product manufacture sometimes differs in amounts of water used. The prime uses of water in industry are for cooling or condensing, and for product processing. Significant losses of industrial water by evaporation or consumption in the product can occur and frequently water can be re-used within the plant. Experience has shown that without ample water for industrial use, area development can be greatly curtailed. Water is one of the prime requisites in attracting new industry to a site whether it be required for product manufacture or merely for sanitary use and fire protection. Since the ultimate objective of industry is increased production to meet promoted product demands, ample water must be available to satisfy continuously expanding needs.

Industrial uses of water in the United States during the 55-year period from 1900 to 1955 increased five-fold, or from 10 billion gallons per day in 1900 to 50 billion gallons per day in 1955. On the basis of this increase and various growth stimulating factors, estimates for the 25-year period from 1955 to 1980 indicate that industrial uses of water will be about double the 1955 figure. It is also noted that industrial uses of water in the United States were more than three times the municipal uses in 1900 and 1955, and are estimated to exceed the growing municipal uses estimated for 1980 by a factor of about 3.5.

The increase in industrial water use predicted by Picton (25-year period from 1955 to 1980) is an increase of 135 per cent.[1] Woodward shows increases in industrial uses from 220 to 400 per cent for the 25-year period from 1955 to 1980.[2] Differences in estimated future uses of industrial water by various authors appear to reflect viewpoints on water uses by newly established plants. Conservative estimates include only increased use by existing industries.

Industrial water, for purposes of this investigation, is defined as water obtained from sources other than municipal or district supplies for use in the manufacture of a product or products including in-plant uses for processing, cooling, and sanitation purposes. In cases where industrial water requirements include uses in the steam generation of electricity, this use is shown separately.

Total area industrial water requirements are computed to the year 2010 by expanding 1960 industrial uses at an annual rate consistent with economic evaluations prepared by the OBE, Department of Commerce, for the Potomac Basin. Depending upon economic growth and predicted population figures, annual industrial water requirement rates used for various areas may range from 1 to 5 per cent of 1960 uses (maximum increase of 250 per cent by the year 2010). Areas where known industrial development is taking place, but for which industrial water requirements are not shown reflect types of industries requiring relatively small quantities of water, the quantities of which are reflected in municipal and district water requirements.

CRITERIA FOR DETERMINING FLOW REQUIREMENTS FOR POLLUTION ABATEMENT PURPOSES

Natural water quality is altered by man in as many or more ways as there are numbers of polluting substances. Materials of certain types and quantities when disposed of to stream water can unbalance the biological equilibrium of the stream, reduce recreational values, prevent use of stream water for municipal and industrial purposes, and in some instances create serious nuisances and public health hazards, all of which become liabilities to the area affected.

In many instances methods and facilities for treating wastes before discharge to streams have barely kept up with new production facilities and population growths because of the additional pollution created by new sources and increasing quantities of wastes from existing sources. In many areas the end result is very little if any improvement in the quality of receiving stream waters compared

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[1] W. L. Picton, " Water Use in the United States, 1900-1980," Business Service Bulletin, Department of Commerce, (March, 1960).

[2] D. R. Woodward, "Availability of Water in the United States with Special Reference to Industrial Needs by 1980," Industrial College of the Armed Forces, Washington, D. C., 1956-1957.

with conditions existing when improvement was initially required. Treatment plant effluents contain reduced waste concentrations and materials not removed by conventional treatment methods, and because of increasing volumes may possess total loads greater than can be tolerated in the stream.

The characteristics of waste effluents change with refinements in treatment methods, sometimes for the betterment and other times to the detriment of receiving stream water. It is becoming more evident that highly treated wastes promote nutrient enrichments which stimulate algal nuisances in lakes, estuaries, and impoundments, where less highly treated wastes formerly had not promoted such nuisances. In such instances the respiration and decay of algal cells can have as great or greater detrimental effect than that produced directly by lesser treated wastes.

Therefore, increased stream flow has particularly great value during extreme drought periods when concentrations of nutrients are highest and where waste treatment is not sufficient to protect the receiving stream. The value of such flows for benefit computation purposes would be equivalent to greater than present day conventional treatment costs, or equivalent to the cost involved in attaining certain levels of tertiary treatment. However, it should be pointed out that tertiary treatment as now known would not be the equivalent of low flow augmentation that would provide similar reduction in oxygen demanding substances. Since it is not known to what extent waste load reductions by future treatment methods will exceed present conventional treatment efficiencies, stream flow requirements for pollution abatement are determined as that flow which in combination with optimum municipal and industrial treatment efficiencies presently possible, will result in desired improvement or meeting of the objective for stream water quality. To determine future municipal and industrial waste loads a factor relating to populations and projected water use is applied.

The stream BOD loads from waste effluent sources, together with the effects of these loads on dissolved oxygen levels in the stream, are used as a basis for determining minimum flow requirements. Whereas other pollutional parameters exist, these parameters offer a convenient means of determining benefits based on costs to obtain BOD reductions, with available treatment facilities, similar to assimilated reductions achieved with the augmented flow. In some instances it may be necessary to base water quality objectives on waste substances not removed by conventional treatment. In this event, flow requirements may be based on dilution requirements to control concentrations of these substances. Specifically, the estimated flow requirements for pollution abatement given in this report are those which in combination with treated waste loads result in a minimum 5.0 ppm dissolved oxygen (60 per cent saturation at 26°C.) in the stream.

Where several waste loads are received in a given stream reach, the BOD loads from each source are accumulated with proper allowances for assimilation between sources, to a point or points of maximum stream loading. The required flow given is that which in combination with the BOD load and stream assimilative capacity at the point of maximum loading, results in the 60 per cent saturation figure at the lowest point of the dissolved oxygen sag curve. Purification factors and dissolved oxygen deficits used to compute maximum allowable BOD loads for various stream reaches are estimated from stream sampling data. Figure 52, parts 1-4, show graphically the steps followed in determining future stream flow requirements for abating the pollution effects of oxygen consuming wastes.

REQUIREMENTS FOR WATER SUPPLY AND POLLUTION ABATEMENT IN THE SHENANDOAH RIVER BASIN

GENERAL

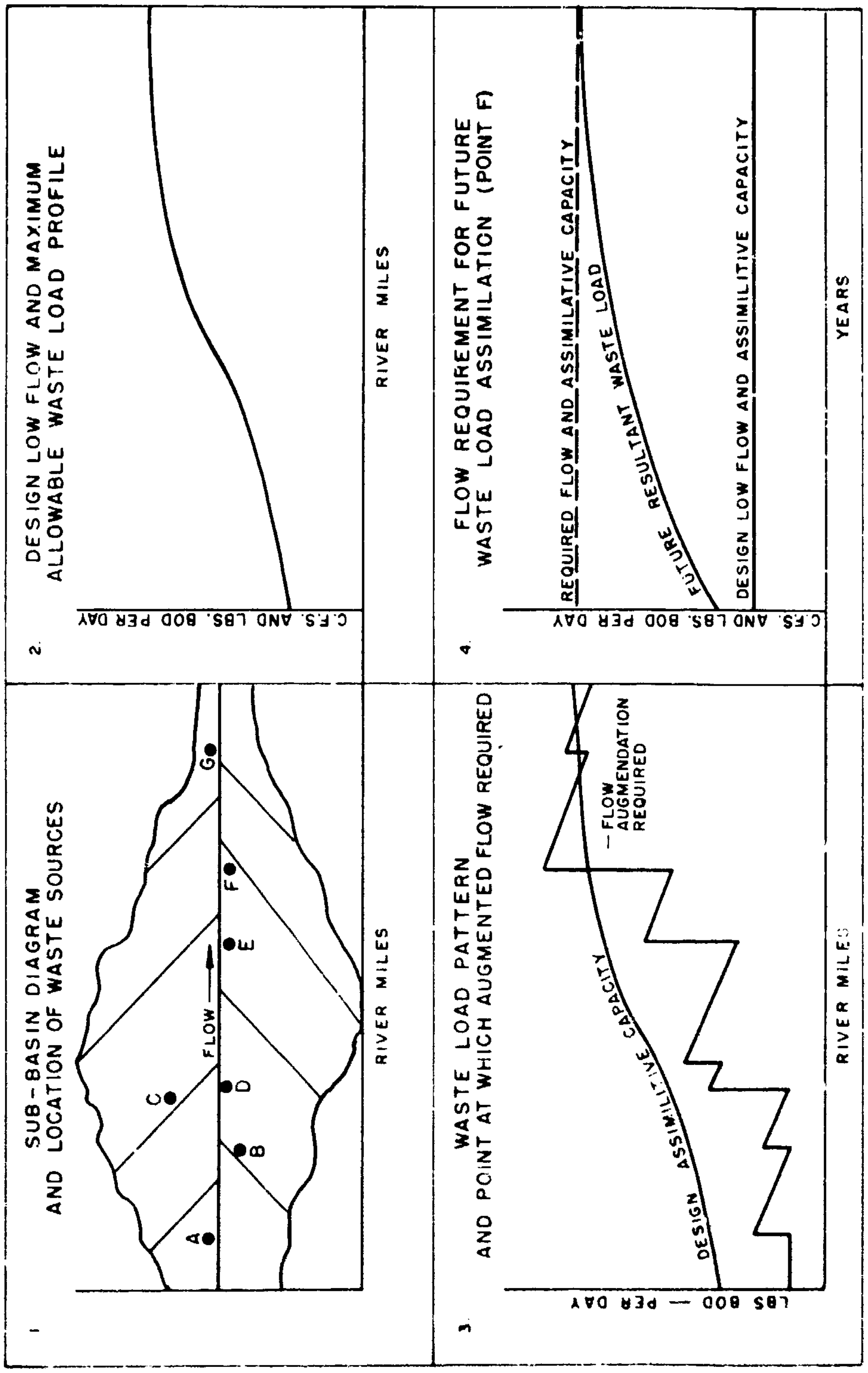
Wide variations in rates and types of area development exist throughout the Shenandoah Valley. Development from one locality to another is influenced by differences in agricultural activities, natural resources, markets, transportation, and labor forces, all of which have a great influence on water requirements.

For evaluation purposes the basin is divided into ten major population subdivisions, including one lying outside of the basin since it is served by a water source located in the Shenandoah Basin (see Figure 53). Each subdivision includes all or parts of various county populations, depending upon the relationship of the populations with respect to major stream water sources, possible reservoir sites, and waste receiving streams.

Table 32 shows the populations involved in the evaluation by counties and residence categories, as adjusted from figures prepared by the Office of Business Economics for the years 1960, 1985, and 2010. The population subdivisions and percentages of county populations included in each for water supply and pollution abatement evaluations are shown in Table 33.

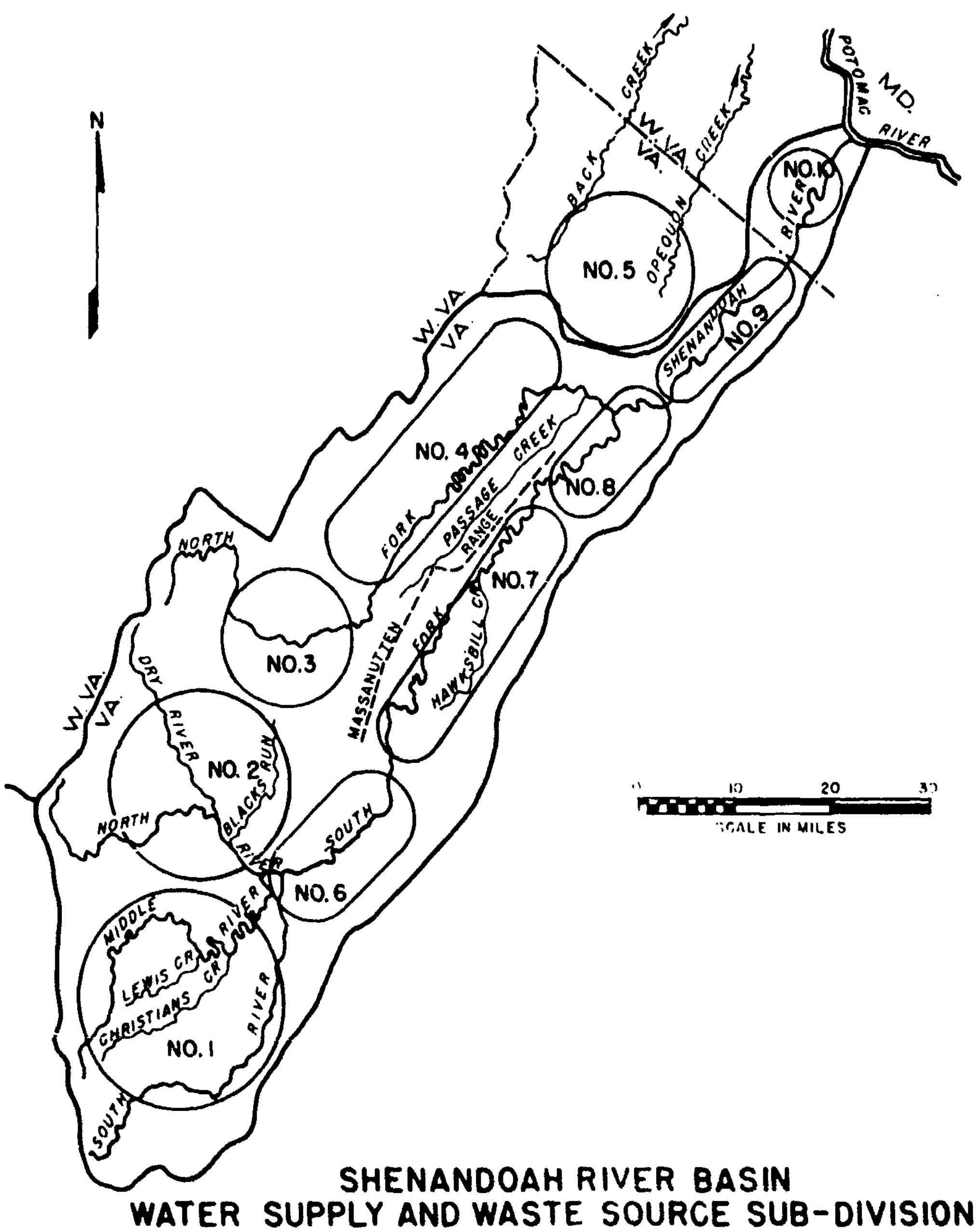
WATER SUPPLY REQUIREMENTS

Because topographic and related economic factors limit to certain areas the distribution of water from central supply systems, not all regional populations are considered in the water requirement evaluations. Farm populations and most small towns are omitted since existing wells, springs, or small stream supplies are expected to supply these needs for the foreseeable future. However, all urban populations and a large percentage of the rural residential populations



GRAPHICAL EXPLANATION OF THE METHOD USED TO DETERMINE FLOW REQUIREMENTS FOR POLLUTION ABATEMENT PURPOSES

FIGURE 52



SHENANDOAH RIVER BASIN
WATER SUPPLY AND WASTE SOURCE SUB-DIVISIONS

FIGURE 53

Table 32

Populations by Counties and Residence Categories
1960 - 2010

County Name	% in Basin	Total	Farm	Non-Farm		
				Rural Residential	Small Town	Urban
			1960			
Augusta	100	75,200	12,400	22,500	400	39,900
Rockingham	"	52,400	13,800	16,400	3,300	18,900
Page	"	15,600	4,100	5,400	400	5,700
Shenandoah	"	21,600	7,200	7,400	2,500	4,500
Warren	"	14,600	2,000	3,900	200	8,500
Clark	"	7,900	2,300	3,300	400	1,900
Frederick	10	3,690	530	1,450	150	1,560
Frederick*	90	33,210	4,770	13,050	1,350	14,040
Jefferson	50	9,300	1,750	3,400	800	3,350
Totals		200,290	44,080	63,750	8,150	84,310
			1985			
Augusta	100	122,500	10,000	34,000	3,300	75,200
Rockingham	"	89,800	11,600	27,400	7,600	43,200
Page	"	21,500	3,600	7,300	700	9,900
Shenandoah	"	30,000	5,900	10,800	4,700	8,600
Warren	"	25,700	1,700	5,600	1,000	17,400
Clark	"	11,200	1,700	5,200	1,000	3,300
Frederick	10	5,990	460	2,380	220	2,930
Frederick*	90	53,910	4,140	21,420	1,980	26,370
Jefferson	50	14,350	1,500	5,450	1,500	5,900
Totals		321,040	36,460	98,130	20,020	166,430

Table 32 (Continued)

Populations by Counties and Residence Categories
1960 - 2010

County Name	% in Basin	Total	Farm	Non-Farm		
				Rural Residential	Small Town	Urban
			2010			
Augusta	100	190,500	9,500	46,000	11,000	124,000
Rockingham	"	145,000	10,000	35,000	23,000	77,000
Page	"	27,500	3,000	8,500	1,000	15,000
Shenandoah	"	39,000	5,500	13,500	7,000	13,000
Warren	"	41,500	1,500	7,500	2,500	30,000
Clark	"	15,000	1,500	6,500	1,500	5,500
Frederick	10	9,890	410	3,300	480	5,700
Frederick*	90	88,010	3,690	29,700	3,320	51,300
Jefferson	50	20,500	1,250	7,500	2,000	9,750
Totals		488,890	32,660	127,800	48,480	279,950

*Not included in basin population totals. Water supplied from Shenandoah Basin and wastes discharged to Opequon and Back Creek Basins.

Table 33

Shenandoah River Basin
Population Subdivisions

Subdivision Number	Location of Subdivision Sub-Basin	County	% County Population
Water Supply			
Sub. No. 1	South River	Augusta	40
	Middle River	Augusta	50
Sub. No. 2	North River	Augusta	10
	North River	Rockingham	50
Sub. No. 3	North Fork	Rockingham	25
Sub. No. 4	North Fork	Shenandoah	100
	North Fork	Frederick	10
Sub. No. 5	North Fork	Frederick	90
Sub. No. 6	South Fork	Rockingham	25
Sub. No. 7	South Fork	Page	100
Sub. No. 8	[illegible] Fork	Warren	85
Sub. No. 9	Shenandoah River	Warren	15
	Shenandoah River	Clark	100
Sub. No. 10	Shenandoah River	Jefferson	50
Pollution Abatement			
Sub. No. 1-a	South River	Augusta	40
Sub. No. 1-b	Middle River	Augusta	50
Sub. No. 2	North River	Augusta	10
	North River	Rockingham	50
Sub. No. 3	North Fork	Rockingham	25
Sub. No. 4-a	North Fork	Shenandoah	50
Sub. No. 4-b	North Fork	Shenandoah	50
	North Fork	Frederick	10
Sub. No. (5)*	North Fork	Frederick	90
Sub. No. 6	South Fork	Rockingham	25
Sub. No. 7	South Fork	Page	100
Sub. No. 8	South Fork	Warren	85
Sub. No. 9	Shenandoah River	Warren	15
	Shenandoah River	Clark	100
Sub. No. 10	Shenandoah River	Jefferson	50

*Wastes discharged in Opequon and Back Creek Basins

are included in the evaluation and are considered as those served, or to be served in the future, by municipal or district water supply systems. Table 34 lists the subdivision populations on which municipal - district supply requirements are based. Except for subdivision No. 1, all subdivision municipal - district populations include 50 per cent of the rural residential populations for 1985 and 75 per cent to the rural residential populations for the year 2010. Since sanitary districts are presently in existence in subdivision No. 1, 75 and 85 per cent of the rural residential populations are used for the years 1985 and 2010, respectively. Where small town populations are projected to more than a total of 10,000 in any one subdivision, 50 per cent of these populations are included in the municipal - district water requirements.

The per capita water uses that are applied to populations in the various subdivisions are shown in Table 35. The projected average per capita figures reflect the 1.5 per cent yearly increase from 1960, as previously established. The maximum daily per capita demands include 50 per cent of 1960 daily average figure added to the projected increases.

Future industrial water requirements are based only on an expansion of existing uses and therefore could be extremely conservative. Industrial water requirements for subdivisions 1, 3, 7, 8, and 10 are estimated to increase at the rate of 5 per cent per year from estimated 1960 quantities, and for subdivision 6, at 4 per cent per year. Table 36 shows the water requirements for both municipal - district and industrial uses by subdivisions for the years 1960, 1985, and 2010. The steam-electric water requirements shown for subdivision 3 are based on an increase of 10 per cent per year from 1960, and for subdivisions 9 and 10, an increase of 7.5 per cent per year. These increases are based on estimates of relative area growth and on the fact that the national demands for power appear to double approximately every decade. Alternate methods of cooling or the development of more efficient water cooling practices could considerably alter the water requirements for steam-electric power production shown.

Projected water supply demand curves and relationships of these demands to minimum stream flows (1930 low flow) in each population subdivision are shown in Figures 54 through 63.

The 1-day, 30 year minimum stream flows or dependable surface water supplies shown in Figures 54 through 63 constitute essentially the 1930 minimum flows of record at several gaging stations in the region, adjusted by drainage area to possible water supply intake points relative to the water supply demand areas.

Table 34

Subdivision Populations Served by Municipal and District Supply Systems

Sub-Basin	Subdivision Number	Municipal Dist. Populations 1960	1985	2010
South and Middle Rivers	1			
Rural Residential		12,540	23,000	35,200
Small Town		-	-	4,950
Urban		35,910	67,680	112,000
Total		48,450	90,680	152,150
North River	2			
Rural Residential		3,980	8,550	15,800
Small Town		-	-	6,300
Urban		13,440	29,120	51,000
Total		17,420	37,670	73,100
North Fork	3			
Rural Residential		-	3,425	6,560
Urban		4,725	10,800	19,250
Total		4,725	14,225	25,810
North Fork	4			
Rural Residential		1,440	6,590	12,600
Urban		5,060	11,530	18,700
Total		6,500	18,120	31,300
North Fork	5			
Rural Residential		6,000	10,710	22,300
Urban		14,040	26,370	51,300
Total		20,040	37,080	73,600
South Fork	6			
Rural Residential		-	3,425	6,560
Urban		4,725	10,800	19,250
Total		4,725	14,225	25,810
South Fork	7			
Rural Residential		-	3,650	6,400
Urban		5,700	9,900	15,000
Total		5,700	13,550	21,400
South Fork	8			
Rural Residential		2,000	2,300	4,750
Urban		7,200	14,800	25,500
Total		9,200	17,100	30,250

Table 34 (Continued)

Subdivision Populations Served by Municipal and District Supply Systems

Sub-Basin	Subdivision Number	Municipal-Dist. Populations 1960	1985	2010
Shenandoah River	9			
Rural Residential		-	3,000	5,750
Urban		3,200	5,900	10,000
Total		3,200	8,900	15,750
Shenandoah River	10			
Rural Residential		-	2,725	5,650
Urban		3,350	5,900	9,750
Total		3,350	8,625	15,400

Table 35

Per Capita Daily Municipal and District Water Requirements by Subdivisions

Sub-Basin	Subdivision Number	Per Capita Daily Gal. 1960	1985	2010
South and Middle Rivers	1			
Average		85	117	149
Maximum		128	160	192
North River	2			
Average		133	183	233
Maximum		200	250	300
North Fork	3			
Average		138	190	242
Maximum		207	259	311
North Fork	4			
Average		110	151	193
Maximum		165	206	248
North Fork	5			
Average		150	206	263
Maximum		225	281	338
South Fork	6			
Average		105	144	183
Maximum		157	196	235
South Fork	7			
Average		105	144	184
Maximum		158	197	237
South Fork	8			
Average		109	149	191
Maximum		164	205	246
Shenandoah River	9			
Average		110	151	193
Maximum		165	206	248
Shenandoah River	10			
Average		125	172	218
Maximum		188	235	282

Table 36

Municipal, District, and Industrial
Water Requirements by Subdivisions

Sub-Basin	Subdivision Number	Million Gallons per Day 1960	1985	2010
South and Middle Rivers-	1			
Municipal - District				
Average		4.1	10.6	22.7
Maximum		6.2	14.5	29.2
Industrial				
Processing		3.9	8.8	13.7
Cooling		11.2	25.2	39.2
Totals				
Average		19.2	44.6	75.6
Maximum		21.3	48.5	82.1
North River	2			
Municipal - District				
Average		2.3	6.9	17.1
Maximum		3.5	9.4	21.9
North Fork	3			
Municipal - District				
Average		0.7	2.7	6.2
Maximum		1.0	3.7	8.0
Industrial				
Processing		1.0	2.3	3.5
Cooling		0.2	0.5	0.7
Steam-Electric (stand-by)		1.5	5.3	9.0
Totals				
Average		3.4	10.8	20.4
Maximum		3.7	11.8	22.2
North Fork	4			
Municipal - District				
Average		0.7	2.7	6.0
Maximum		1.1	3.7	7.8

Table 36 (Continued)

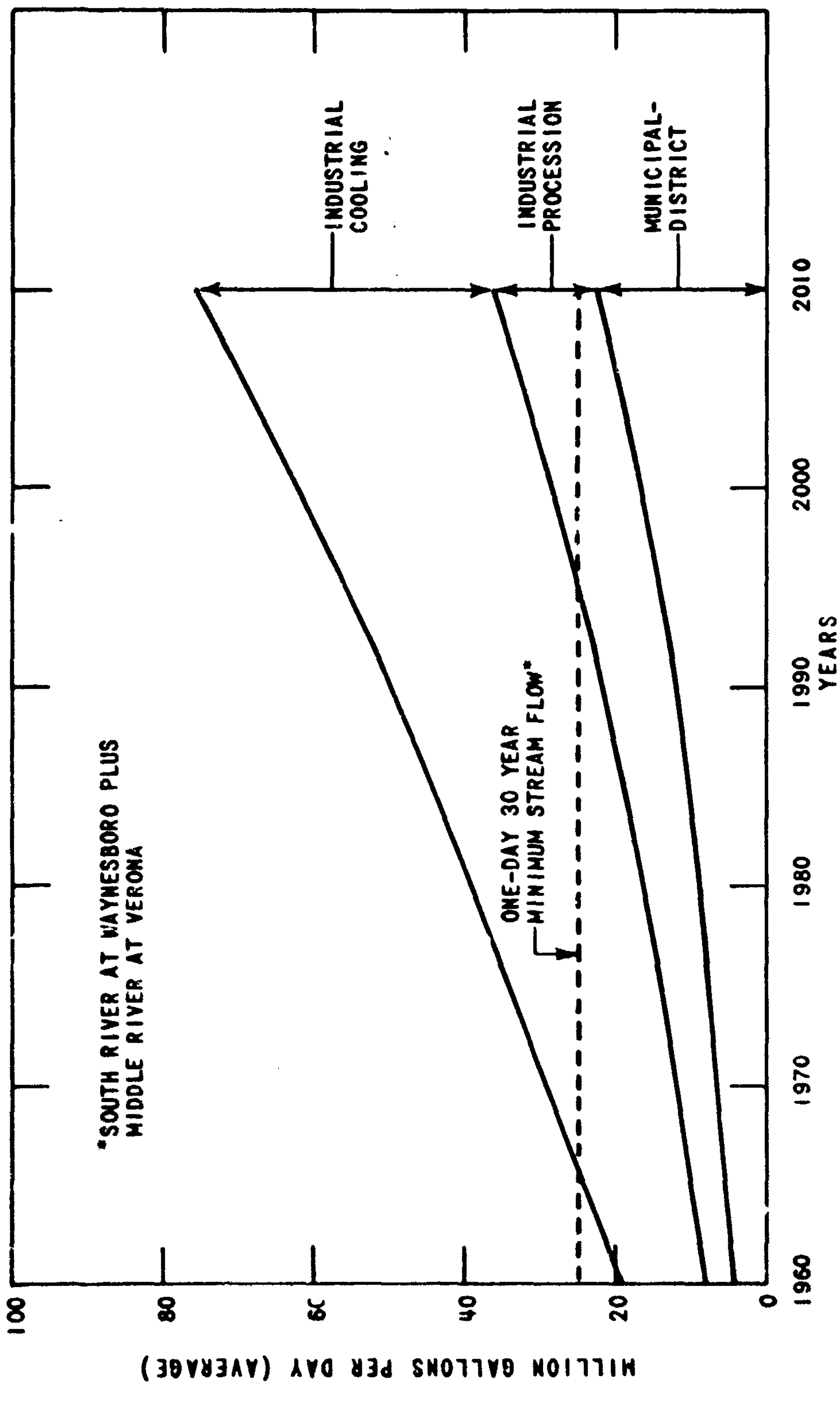
Municipal, District, and Industrial
Water Requirements by Subdivisions

Sub-Basin	Subdivision Number	Million Gallons per Day 1960	1985	2010
North Fork	5			
Municipal - District				
Average		3.0	7.6	19.4
Maximum		4.5	10.4	24.9
South Fork	6			
Municipal - District				
Average		0.5	2.0	4.7
Maximum		0.8	2.8	6.1
Industrial				
Processing		1.3	2.6	3.9
Cooling		7.7	15.4	23.1
Totals				
Average		9.5	20.0	31.7
Maximum		9.8	20.8	33.1
South Fork	7			
Municipal - District				
Average		0.6	2.0	3.9
Maximum		0.9	2.7	5.1
Industrial				
Processing		0.3	0.7	1.1
Totals				
Average		0.9	2.7	5.0
Maximum		1.2	3.4	6.2
South Fork	8			
Municipal - District				
Average		1.0	2.6	5.8
Maximum		1.5	3.5	7.4
Industrial				
Processing		4.6	10.4	16.1
Totals				
Average		5.6	13.0	21.9
Maximum		6.1	13.9	23.5

Table 36 (Continued)

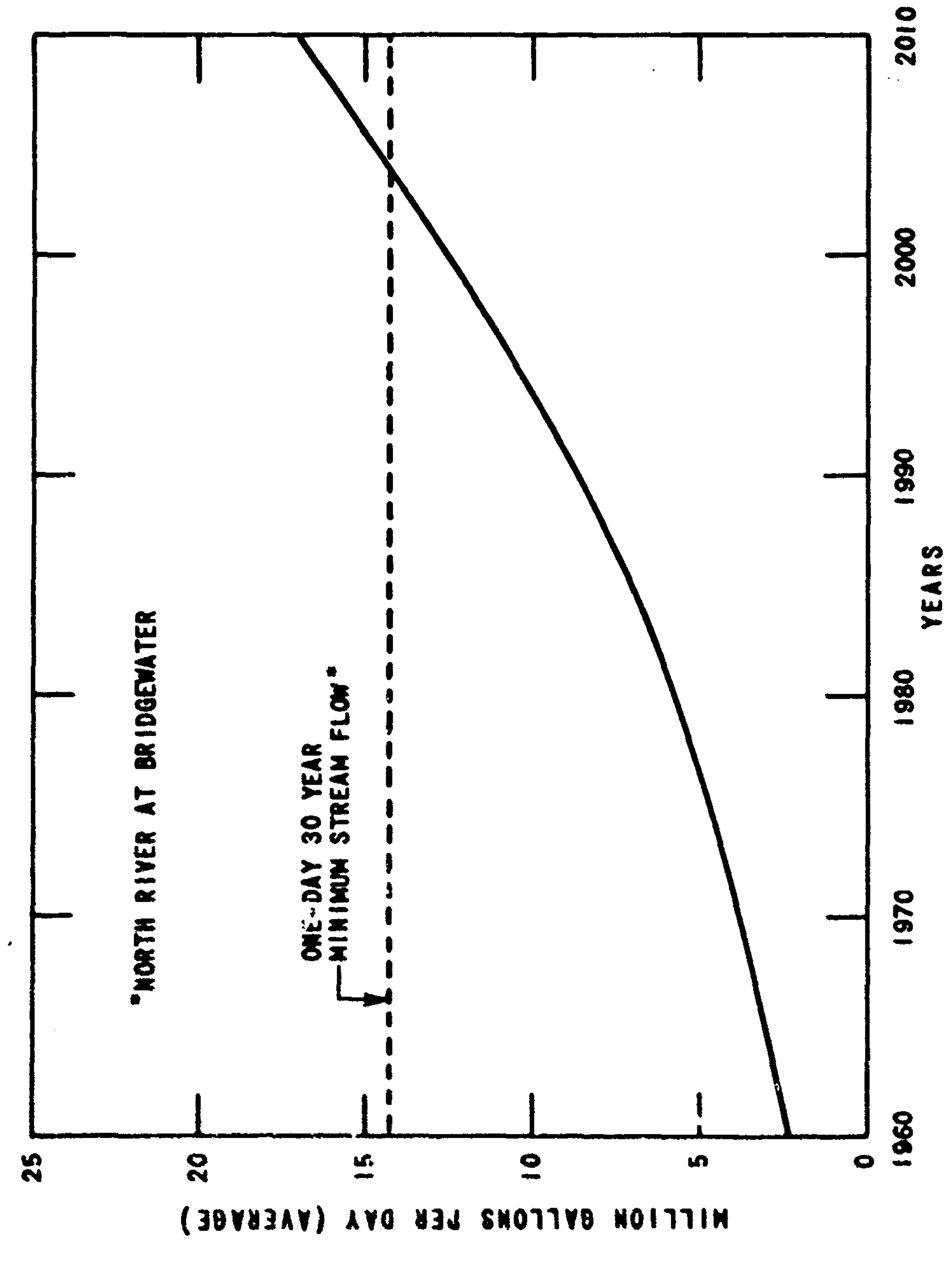
Municipal, District, and Industrial
Water Requirements by Subdivisions

Sub-Basin	Subdivision Number	Million Gallons per Day 1960	1985	2010
Shenandoah River	9			
Municipal - District				
Average		0.4	1.3	3.0
Maximum		0.5	1.8	3.9
Steam-Electric		43.2	123.5	204.0
Totals				
Average		43.6	124.8	207.0
Maximum		43.7	125.0	207.9
Shenandoah River	10			
Municipal - District				
Average		0.4	1.5	3.4
Maximum		0.6	2.0	4.3
Industrial				
Processing		3.6	8.1	12.6
Steam-Electric		21.6	62.1	102.0
Totals				
Average		25.6	71.7	118.0
Maximum		25.8	72.2	118.9



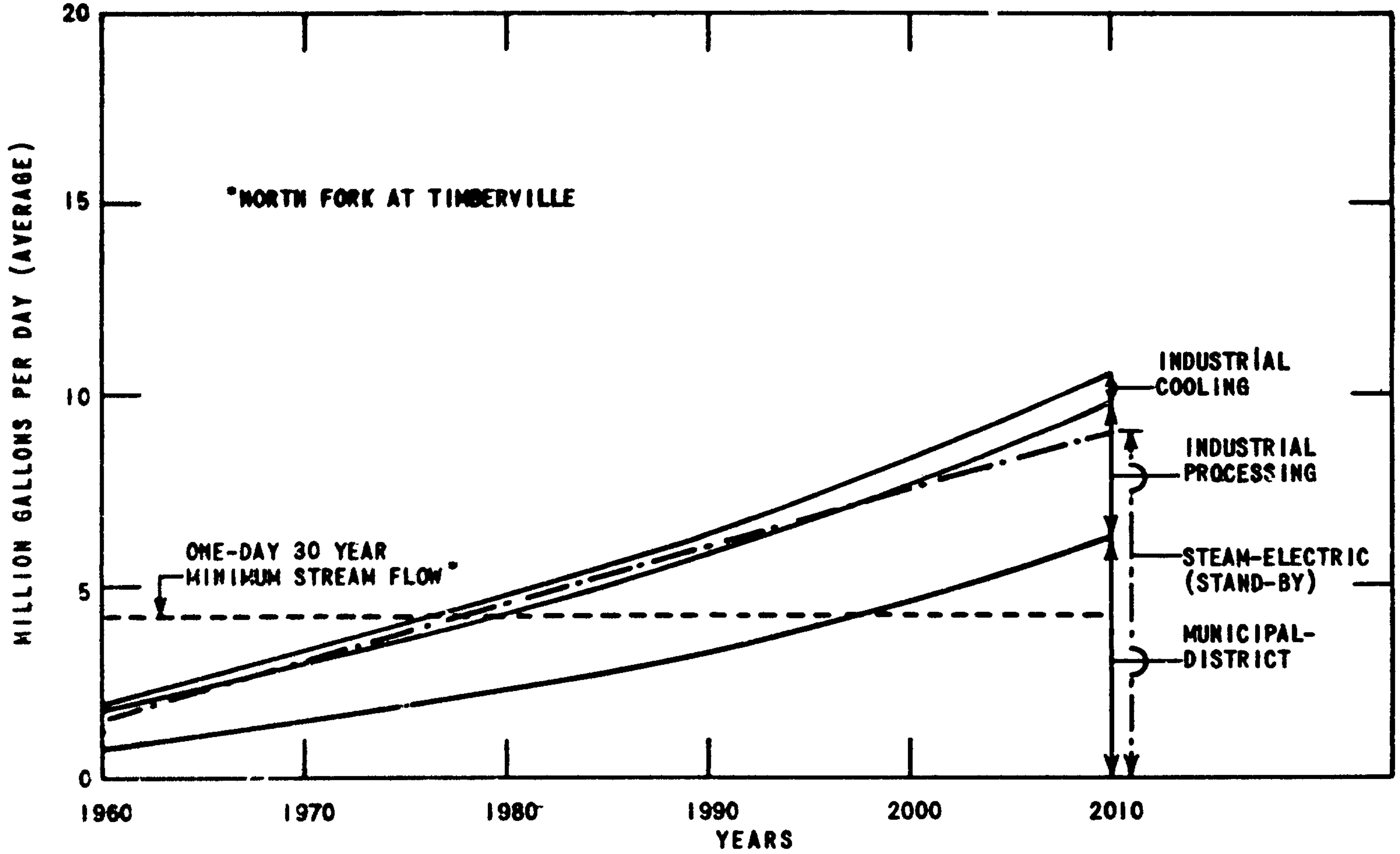
SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT AND INDUSTRIAL WATER SUPPLY REQUIREMENTS
SOUTH AND MIDDLE RIVERS AREA - SUBDIVISION AREA NO. 1

FIGURE 54



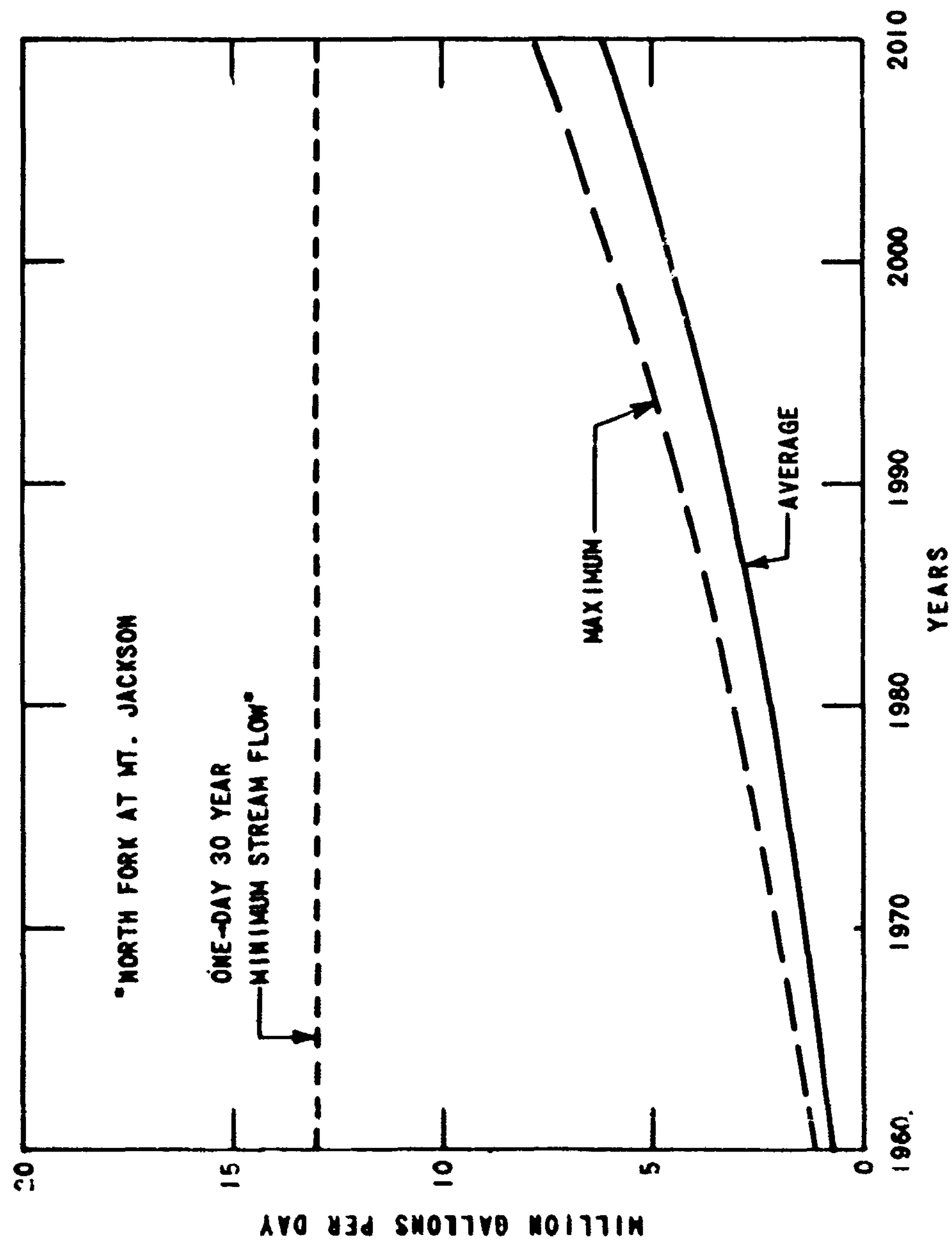
SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT WATER SUPPLY REQUIREMENTS
NORTH RIVER AREA - SUBDIVISION AREA NO. 2

FIGURE 55



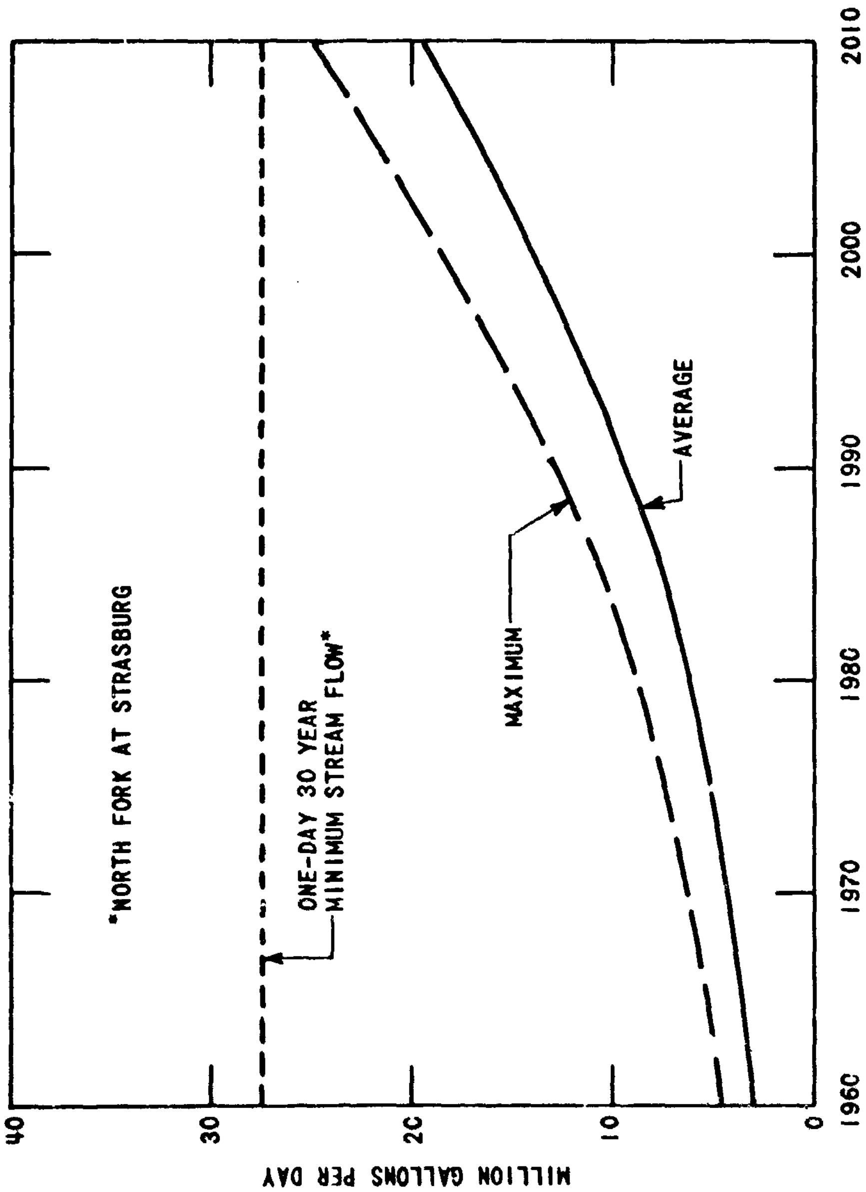
SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT AND INDUSTRIAL WATER SUPPLY REQUIREMENTS
UPPER NORTH FORK AREA - SUBDIVISION AREA NO. 3

FIGURE 56



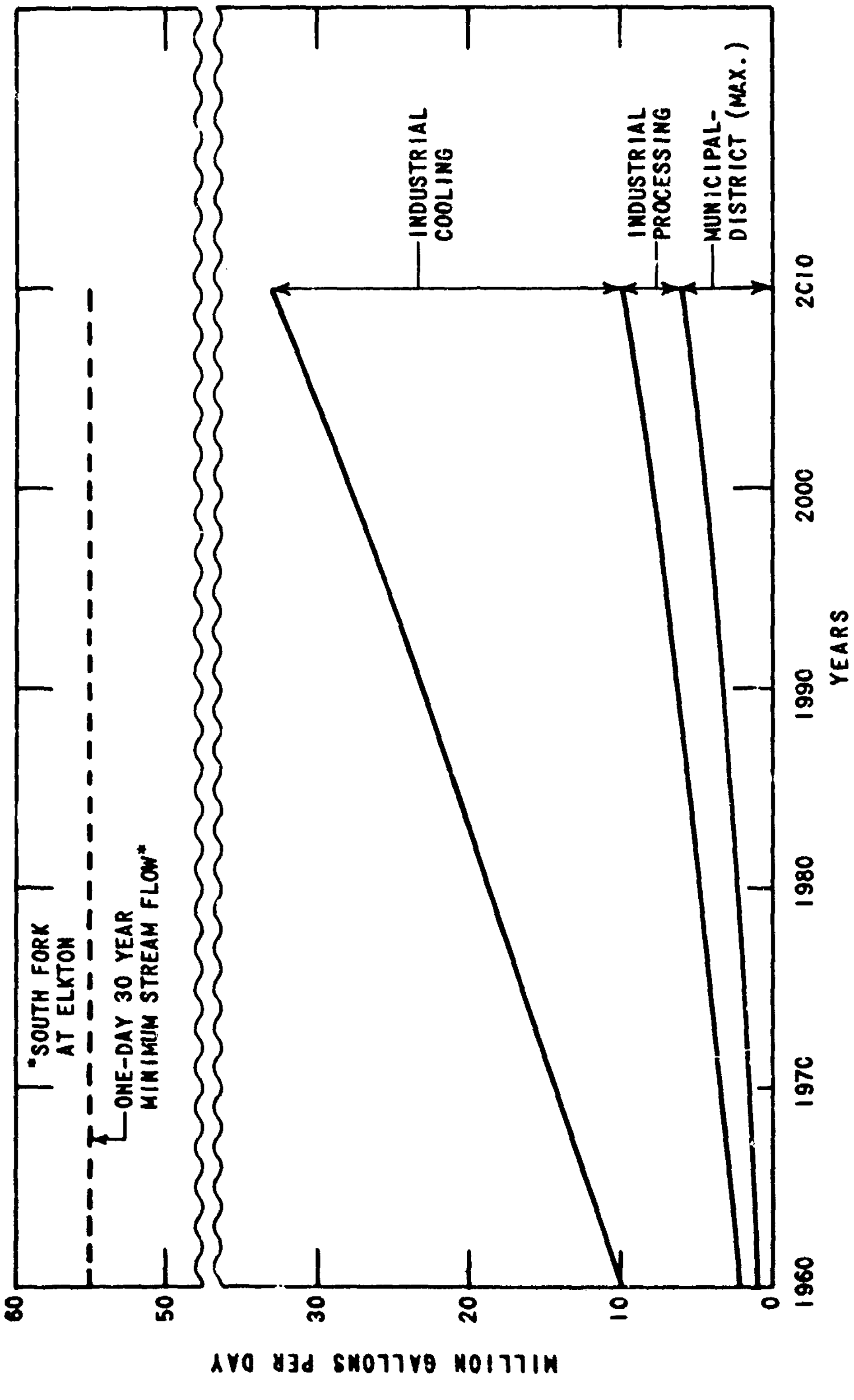
SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT WATER SUPPLY REQUIREMENTS
MIDDLE NORTH FORK AREA - SUBDIVISION AREA NO. 4

FIGURE 57



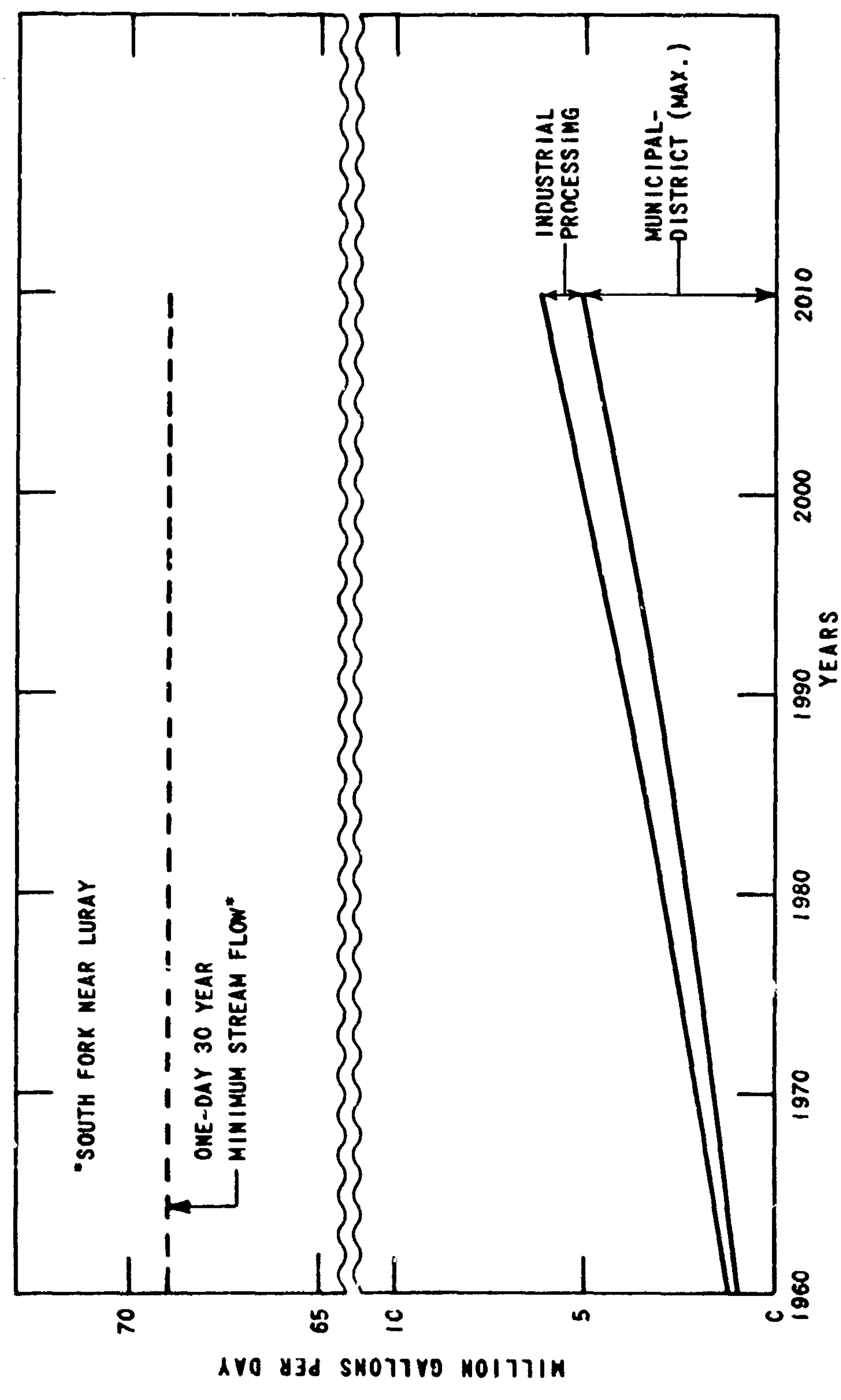
SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT WATER SUPPLY REQUIREMENTS
LOWER NORTH FORK AREA
SUBDIVISION AREA NO. 5

FIGURE 58



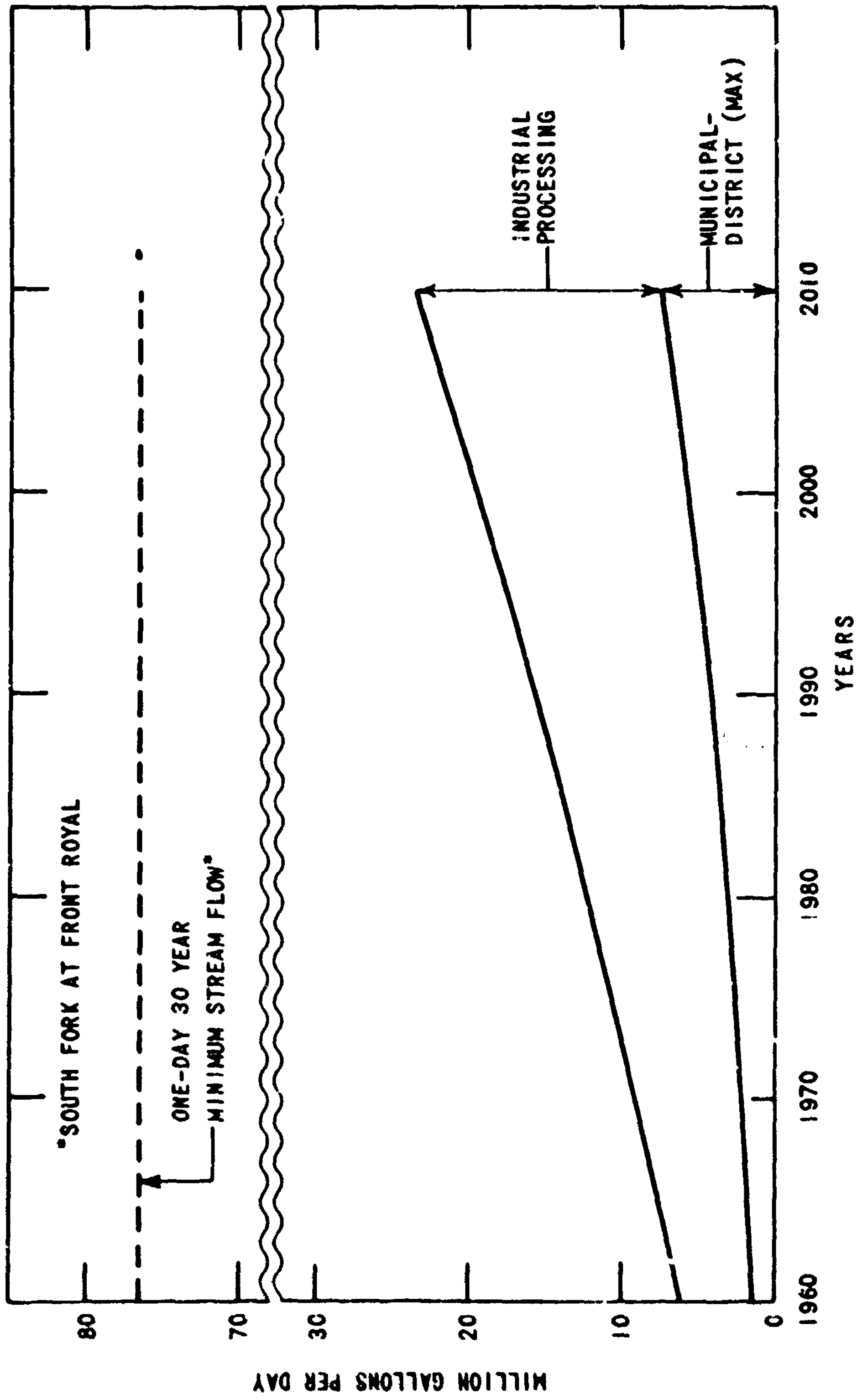
SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT AND INDUSTRIAL WATER SUPPLY REQUIREMENTS
UPPER SOUTH FORK AREA - SUBDIVISION AREA NO. 6

FIGURE 59



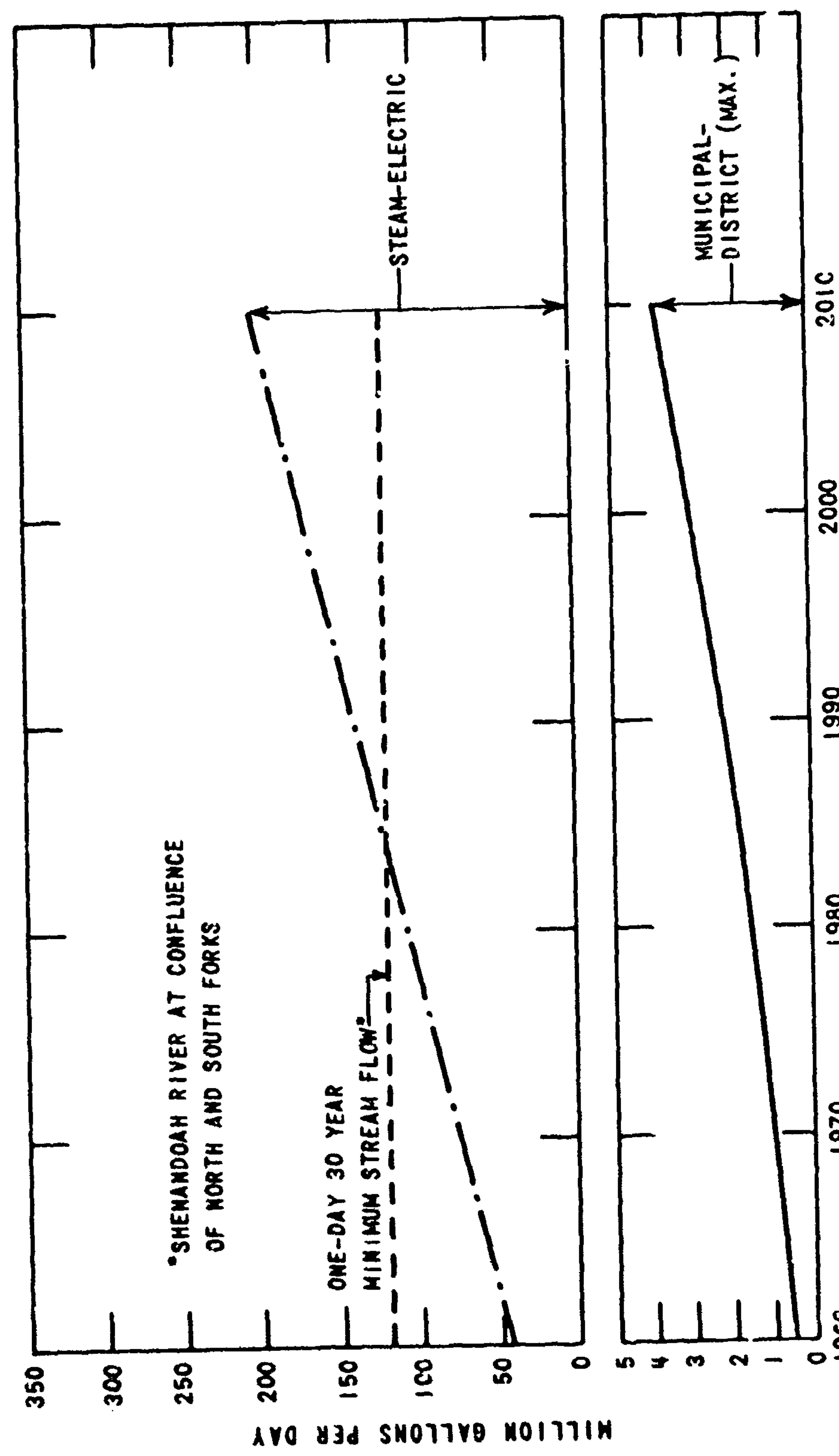
SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT AND INDUSTRIAL WATER SUPPLY REQUIREMENTS
MIDDLE SOUTH FORK AREA - SUBDIVISION AREA NO. 7

FIGURE 60



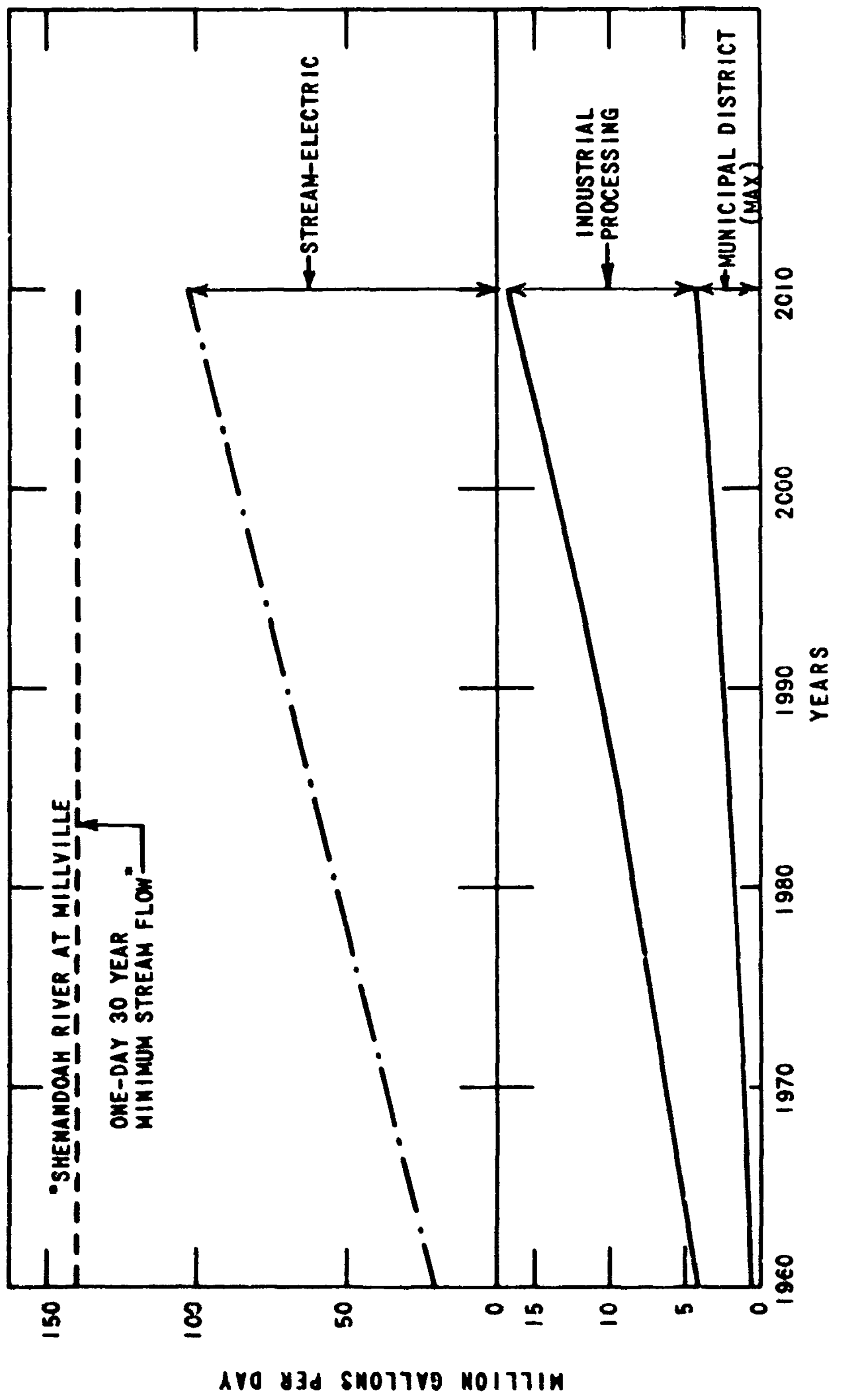
SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT AND INDUSTRIAL WATER SUPPLY REQUIREMENTS
LOWER SOUTH FORK AREA - SUBDIVISION AREA NO. 8

FIGURE 61



SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT AND INDUSTRIAL WATER SUPPLY REQUIREMENTS
UPPER SHENANDOAH RIVER AREA - SUBDIVISION AREA NO. 9

FIGURE 62



SHENANDOAH RIVER BASIN
MUNICIPAL-DISTRICT AND INDUSTRIAL WATER SUPPLY REQUIREMENTS
LOWER SHENANDOAH RIVER AREA - SUBDIVISION AREA NO. 10

FIGURE 63

FLOW REQUIREMENTS FOR POLLUTION ABATEMENT

Associated with increased water uses for domestic and industrial purposes are corresponding increases in waste materials discharged to receiving streams. For purposes of determining future waste loads on which pollution abatement flows are based, it is assumed that most population served by municipal - district water supplies will be served by sewage collection and treatment facilities. Table 37 shows the approximate population by subdivisions served by sewage collection facilities for 1960 and those expected to be served by 1985 and 2010. Populations in subdivision 1 are further divided because two major receiving streams exist within this subdivision. Population in subdivision 4 are also divided since wastes are discharged at several points over a considerable distance of the stream.

Whereas at the present time approximately 55 per cent of the sewage BOD is reduced by treatment in the Shenandoah Basin, pollution abatement flow requirement evaluations assume reductions of 75 per cent BOD for 1960, and 80 and 85 per cent by the years 1985 and 2010, respectively. Table 38 shows the estimated domestic sewage loads discharged after treatment for each subdivision together with treated industrial waste loads expanded at the rate of 1 per cent per year from sources existing in 1960.

From the stream sampling data collected in May - June, 1960, it was found that waste receiving streams and stream reaches varied in waste assimilative capacities, due to differing types of wastes (differences in waste stabilization rates) and the particular physical characteristics of the stream (see Appendix III). Table 39 shows the streams and stream reaches to which wastes from each subdivision are discharged and the assimilative capacity for each stream, expressed in population equivalents per cfs of flow to maintain 5 ppm dissolved oxygen.

Stream flow requirements for pollution abatement based on waste loads and stream assimilative capacities for each subdivision are shown in Table 40. The upstream waste residuals shown reflect rates of deoxygenation and estimated time of stream travel between waste sources. Pollution abatement flow requirement curves for various subdivision areas and stream reaches and relationships of these flows to design minimum average 7-day, 10 year flows are shown in Figures 64 through 72. Although the Virginia State Water Control Board has established no design flow standard for the Shenandoah River, the minimum average 7-day, 10 year flow is used in this basin as well as in others of the Upper Potomac River Basin for reasons of consistency in estimating needs for increased stream flows.

DISCUSSION OF WATER SUPPLY AND POLLUTION ABATEMENT REQUIREMENTS

The water supply requirements given do not necessarily imply that all basin subdivisions would satisfy needs with water taken from

surface sources. For example, high quality spring and well water exists and is used in many areas along the South Fork. Until the time as such supplies would become inadequate, it is assumed that surface water would not be used. It is assumed, however, that any water user presently taking water from a surface source will continue to use this or a similar source in the future, as long as it is economical to do so and provided there is sufficient water available.

In establishing an over-all development plan, it is emphasized that domestic uses be given first priority in the assignment of water quality and quantity, and that further assignments be made to lesser priority uses according to particular water quality requirements of such users.

The stream flows, in combination with waste treatment for pollution abatement, that are shown in relation to design minimum stream flows for various stream reaches indicate at what time and to what extent increased minimum stream flows could be utilized to supplement optimum known treatment plant efficiencies for the achievement of minimum water quality objectives in the Shenandoah River Basin.

It is apparent from the standpoint of satisfying both water supply and pollution abatement requirements that water storage in the headwater areas of the Shenandoah Basin would provide the greatest over-all benefits to the region.

Table 37

Subdivision Populations Served by Sewage Treatment Facilities

Sub-Basin	Subdivision Number	Municipal-Dist. Populations 1960	1985	2010
South River	1-a			
Rural Residential		1,300	10,200	15,640
Urban		15,960	30,080	49,600
Total Sewered		17,260	40,280	65,240
Middle River	1-b			
Rural Residential		4,000	12,750	19,550
Urban		19,500	37,600	62,000
Total Sewered		23,500	50,350	81,550
North River	2			
Rural Residential		-	8,550	16,580
Small Town		-	-	6,300
Urban		13,440	29,120	50,900
Total Sewered		13,440	37,670	73,780
North Fork	3			
Rural Residential		-	3,425	6,550
Urban		4,725	10,800	19,250
Total Sewered		4,725	14,225	25,800
North Fork	4-a			
Rural Residential		-	2,700	5,060
Urban		2,250	4,300	6,500
Total Sewered		2,250	7,000	11,560
North Fork	4-b			
Rural Residential		-	3,890	7,540
Urban		3,800	7,230	12,200
Total Sewered		3,800	11,120	19,740
North Fork	5	Wastes discharged in Opequon and Back Creek Basin.		

Table 37 (Continued)

Subdivision Populations Served by
Sewage Treatment Facilities

Sub-Basin	Subdivision Number	Municipal-Dist. Populations 1960	1985	2010
South Fork	6			
Rural Residential		-	3,425	6,550
Urban		4,725	10,800	19,250
Total Severed		4,725	14,225	25,800
South Fork	7			
Rural Residential				
Urban		-	3,650	6,400
Total Severed		5,700	9,900	15,000
		5,700	13,550	21,400
South Fork	8			
Rural Residential		-	2,380	4,750
Urban		7,200	14,800	25,500
Total Severed		7,200	17,180	30,250
Shenandoah River	9			
Rural Residential		-	3,000	5,750
Urban		3,200	5,900	10,000
Total Severed		3,200	8,900	15,750
Shenandoah River	10			
Rural Residential		-	2,725	5,650
Urban		3,350	5,900	9,750
Total Severed		3,350	8,625	15,400

Table 38

Municipal - District and Industrial Waste Effluent
Loads Discharged by Subdivisions

Sub-Basin	Subdivision Number	Pop. Equiv. Discharged 1960	1985	2010
South River	1-a			
Domestic Sewage		4,300	8,060	9,790
Industrial Waste		15,700	19,600	23,500
Total Discharged		20,000	27,660	33,290
Middle River	1-b			
Domestic Sewage		5,900	10,070	12,230
North River	2			
Domestic Sewage		3,350	7,500	11,070
North Fork	3			
Domestic Sewage		1,200	2,850	3,870
Industrial Waste		13,500	16,900	20,500
Total Discharged		14,700	19,750	24,370
North Fork	4-a			
Domestic Sewage		560	1,400	1,680
North Fork	4-b			
Domestic Sewage		950	2,250	3,000
North Fork	5	Wastes discharged in Opequon and Back Creek Basin.		
South Fork	6			
Domestic Sewage		1,180	2,840	3,870
Industrial Waste		31,620	39,500	47,500
Total Discharged		32,800	42,340	51,370
South Fork	7			
Domestic Sewage		1,425	2,710	3,200
Industrial Waste		6,840	8,500	10,020
Total Discharged		8,265	11,210	13,220

Table 38 (Continued)

Municipal - District and Industrial Waste Effluent Loads Discharged by Subdivisions

Sub-Basin	Subdivision Number	Pop. Equiv. Discharged 1960	1985	2010
South Fork	8			
Domestic Sewage		1,800	3,400	4,550
Industrial Waste		22,990	28,740	34,500
Total Discharged		24,790	32,140	39,050
Shenandoah River	9			
Domestic Sewage		800	1,780	2,350
Shenandoah River				
Domestic Sewage		840	1,720	2,250
Industrial Waste		3,600	4,500	5,400
Total Discharged		4,440	6,220	7,650

Table 39

Receiving Streams and Waste Assimilative Capacities
Corresponding to Subdivision Waste Sources

Stream Name and Waste Receiving Reach	Subdivision Number	Assimilation Capacity Pop. Equiv./cfs
South River Stuarts Draft - Waynesboro	1-a	144
Middle River Verona - Staunton	1-b	144
North River Bridgewater - Harrisonburg	2	144
North Fork Broadway - Timberville	3	144
North Fork New Market - Edinburg	4-a	144
North Fork Woodstock - Riverton	4-b	144
North Fork	5	Wastes discharged to Opequon and Back Creek Basin.
South Fork Port Republic - Elkton	6	192
South Fork Shenandoah - Bentonville	7	156
South Fork Front Royal	8	156
Shenandoah River Riverton - Berryville	9	102
Shenandoah River Charles Town - Harpers Ferry	10	102

Table 40

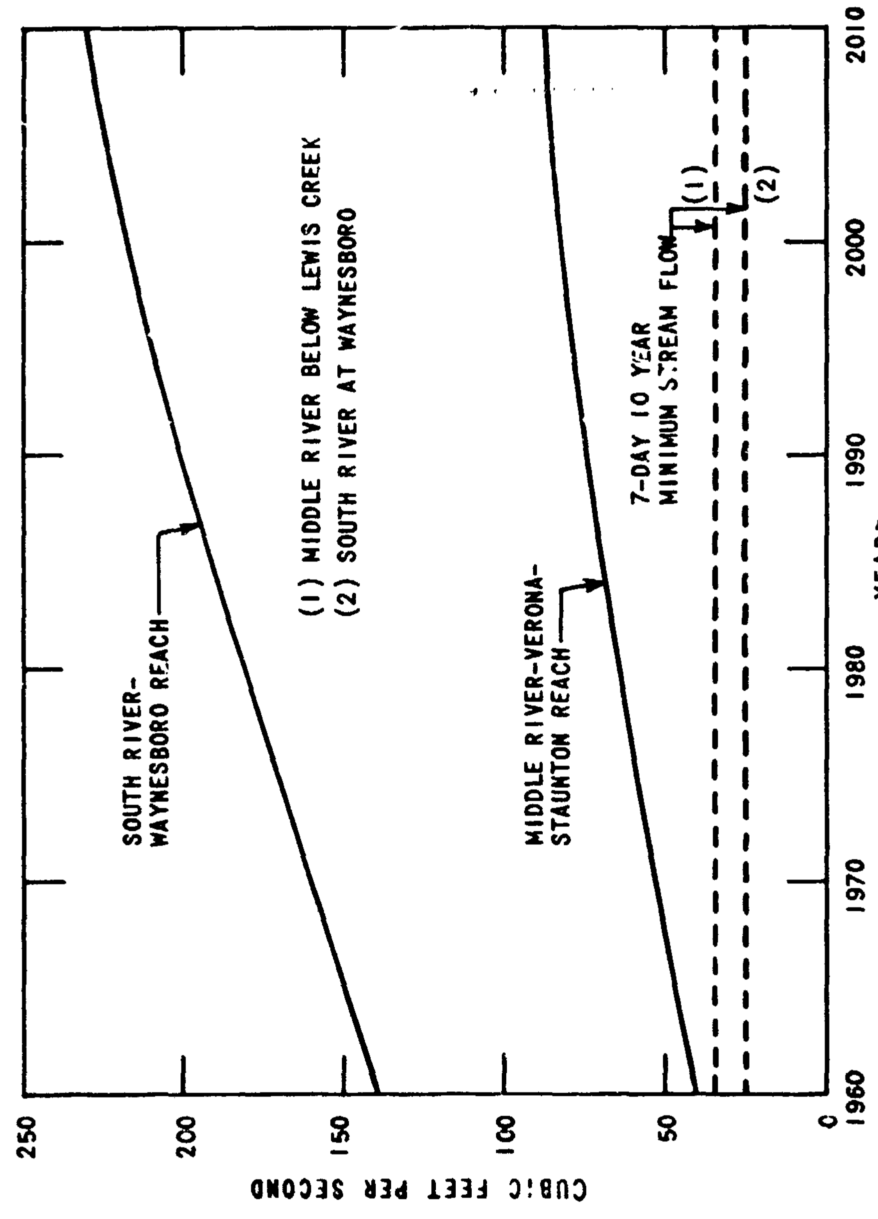
Flow Requirements for Pollution Abatement
by Subdivision Stream Reaches

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
South River	1-a			
Waynesboro				
P.E. Received		20,000	27,660	33,290
CFS Required		139	192	231
Middle River	1-b			
Verona - Staunton				
P.E. Received		5,900	10,070	12,330
CFS Required		40.5	70	85
North River	2			
Bridgewater - Harrisonburg				
P.E. Received		3,350	7,500	11,070
CFS Required		23.5	52	77
North Fork	3			
Broadway - Timberville				
P.E. Received		14,700	19,750	24,370
CFS Required		102	137	169
North Fork	4-a			
New Market - Edinburg				
P.E. Received		560	1,400	1,680
Upstream Residual		9,260	12,400	15,350
Total Received		9,820	13,800	17,030
CFS Required		68	96	118
North Fork	4-b			
Woodstock - Strasburg				
P.E. Received		950	2,250	3,000
Upstream Residual		3,900	5,500	6,810
Total Received		4,850	7,750	9,810
CFS Required		33.5	54.0	68
North Fork	5	Wastes discharged in Opequon and Back Creek Basin.		

Table 40 (Continued)

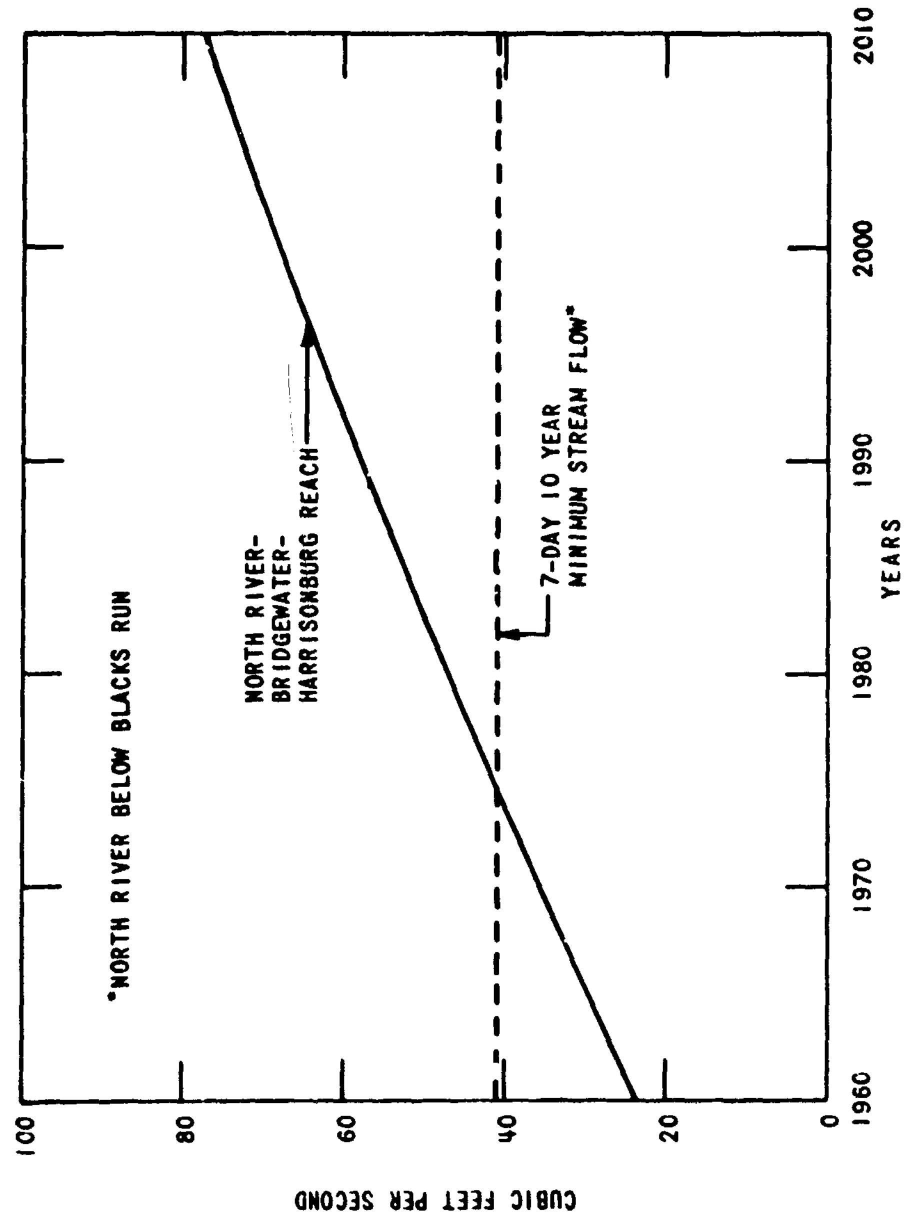
Flow Requirements for Pollution Abatement
by Subdivision Stream Reaches

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
South Fork	6			
Port Republic - Elkton				
P.E. Received		32,800	42,340	51,370
Upstream Residual		16,300	24,450	30,290
Total Received		49,100	66,790	81,660
CFS Required		256	348	425
South Fork	7			
Shenandoah - Bentonville				
P.E. Received		8,265	11,210	13,220
Upstream Residual		30,830	42,080	51,450
Total Received		39,200	53,290	64,670
CFS Required		251	342	415
South Fork	8			
Front Royal				
P.E. Received		24,790	32,140	39,050
Upstream Residual		12,540	17,050	20,690
Total Received		37,330	49,190	59,740
CFS Required		239	315	383
Shenandoah River	9			
Riverton - Berryville				
P.E. Received		800	1,780	2,350
Upstream Residual		23,930	32,450	39,640
Total Received		24,780	34,230	41,990
CFS Required		243	336	412
Shenandoah River	10			
Charles Town - Harpers Ferry				
P.E. Received		4,440	6,220	7,650
Upstream Residual		19,820	27,390	33,590
Total Received		24,260	33,610	41,240
CFS Required		238	329	404



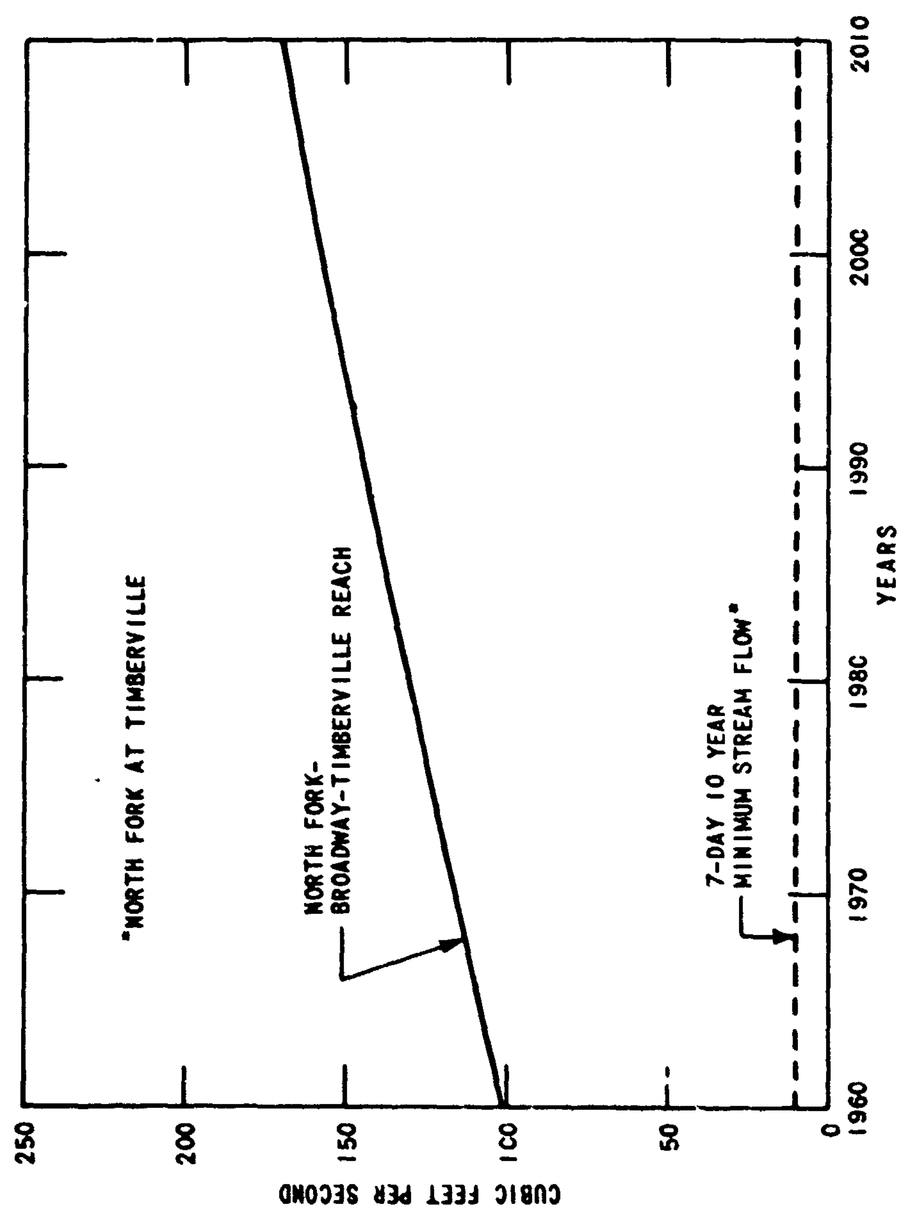
SHENANDOAH RIVER BASIN
FLOW REQUIREMENTS FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NOS. 1-a AND 1-b

FIGURE 64



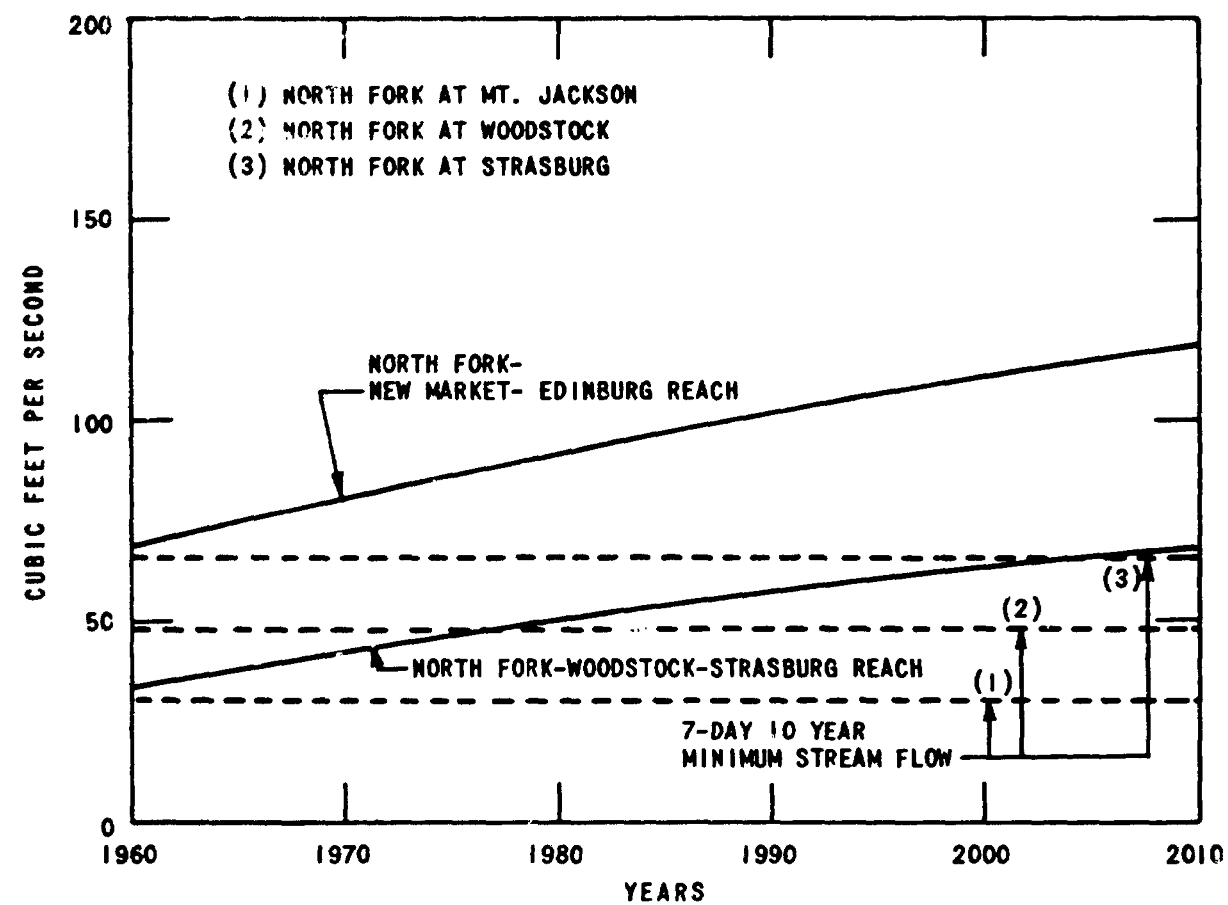
SHENANDOAH RIVER BASIN
FLOW REQUIREMENT FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NO. 2

FIGURE 65



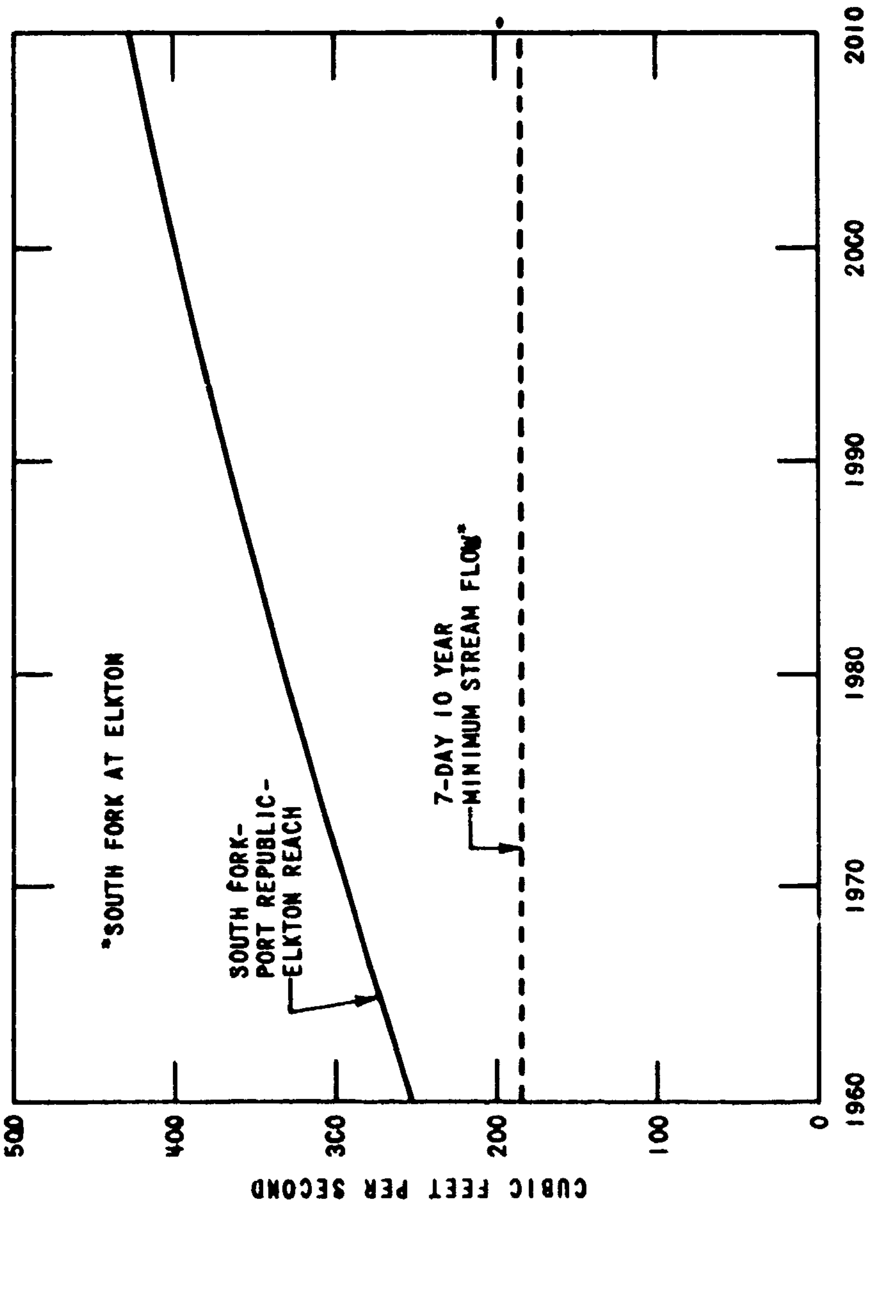
SHENANDOAH RIVER BASIN
FLOW REQUIREMENT FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NO. 3

FIGURE 66



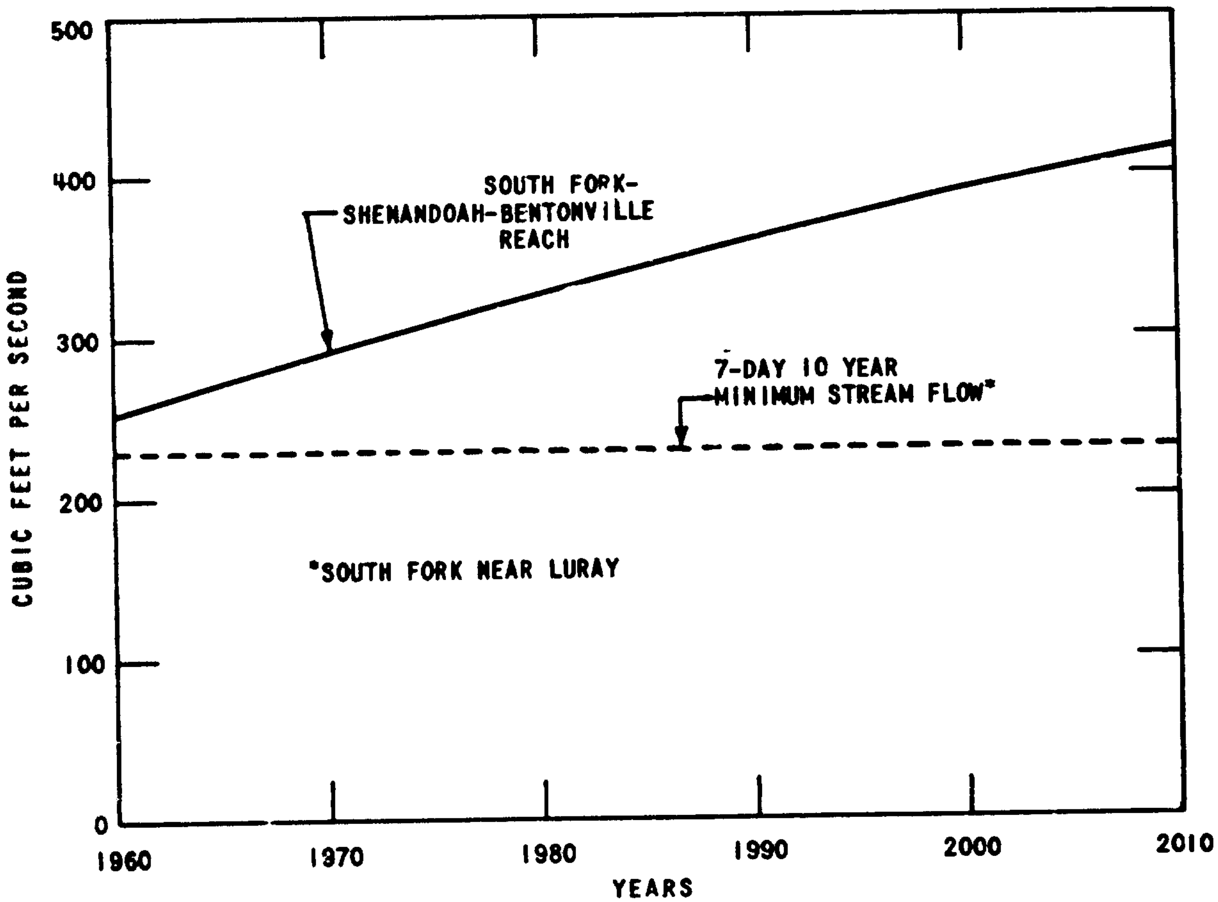
SHENANDOAH RIVER BASIN
FLOW REQUIREMENTS FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NOS. 4-a AND 4-b

FIGURE 67



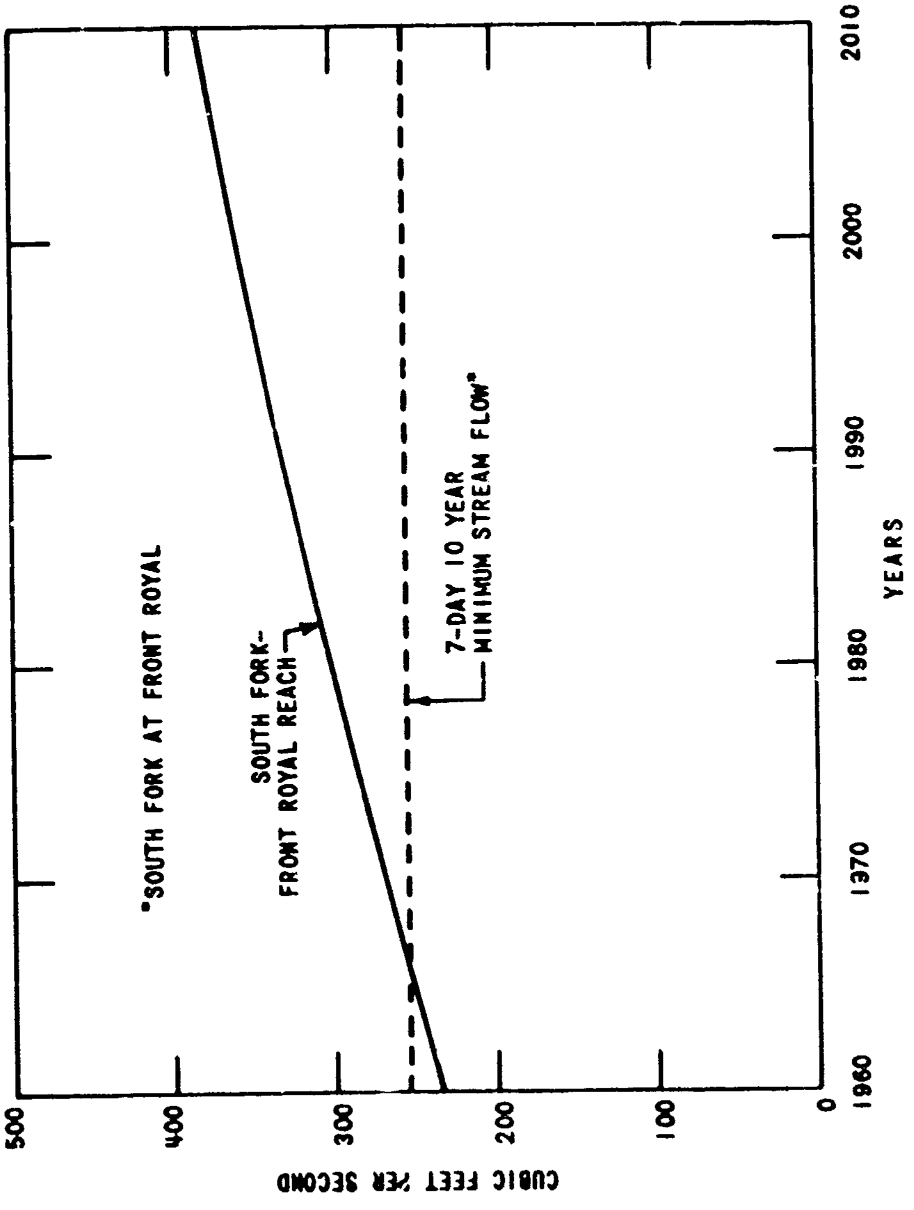
SHENANDOAH RIVER BASIN
FLOW REQUIREMENT FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NO. 6

FIGURE 68



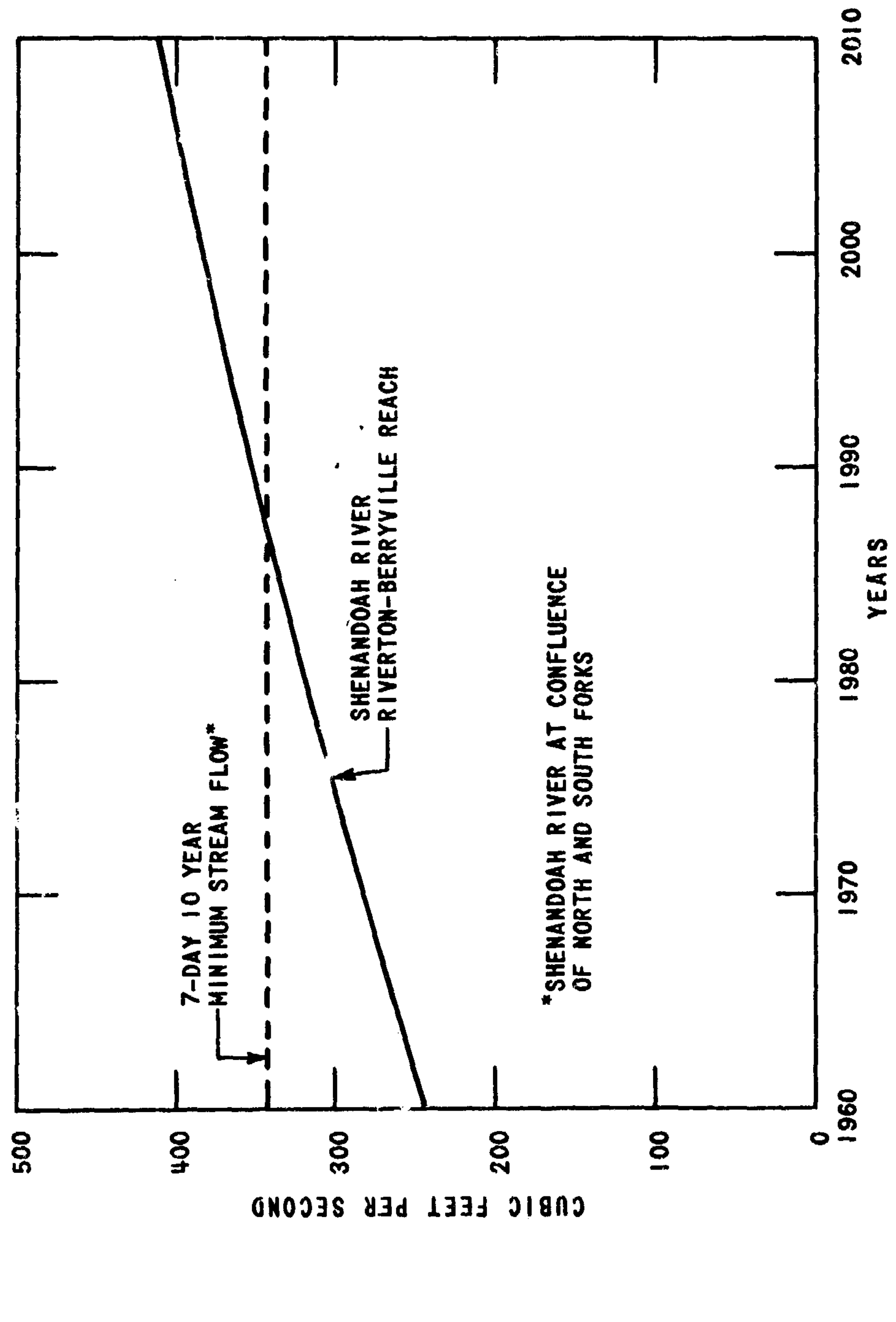
SHENANDOAH RIVER BASIN
FLOW REQUIREMENT FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NO. 7

FIGURE 69



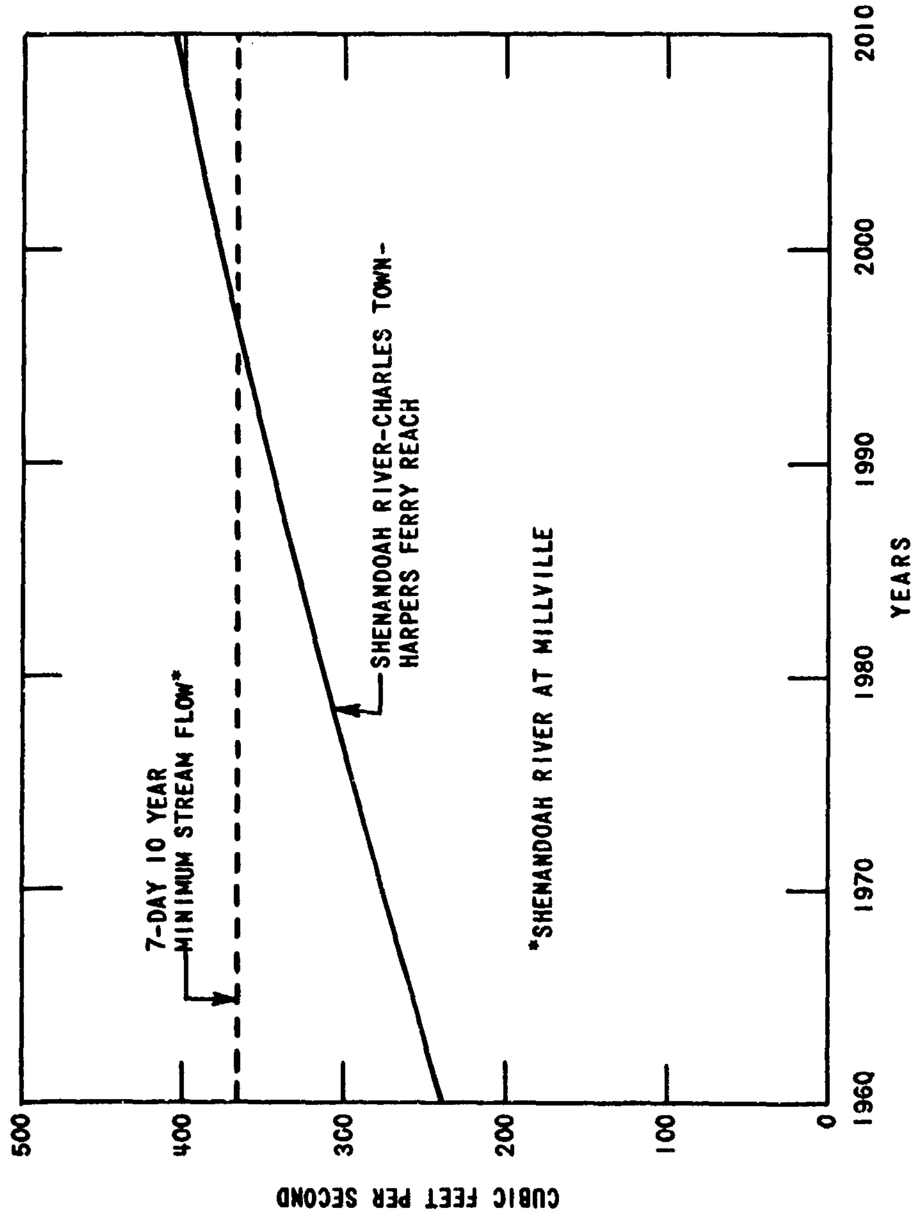
SHENANDOAH RIVER BASIN
FLOW REQUIREMENT FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NO. 8

FIGURE 70



FLOW REQUIREMENT FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NO. 9

FIGURE 71



SHENANDOAH RIVER BASIN
FLOW REQUIREMENT FOR POLLUTION ABATEMENT
INTERSTATE COMMISSION CLASS C D.O. OBJECTIVE
SUBDIVISION AREA NO. 10

FIGURE 72

PART V

APPENDIX I

Public Health Service Stream Survey Data

Grab Samples, May - June, 1960

Stream Survey Data

Grab Samples
May - June 1960

Shenandoah River	Station No.*	Mileage to Mouth	Mileage to Potomac	1960 Date	Time	Flow, cfs	Temp. °C	D.O. ppm	D.O. % Saturation	BOD ppm	BOD lbs/day	Coliform per 100 ml	pH	Alkalinity, ppm Phen.	Alkalinity, ppm Total	Color Co-Pt., Units
South Fork																
South River	S-1			5/16	1130	275	15.5	9.55	91.0	1.65	2,450	430	7.7	0	55.0	12
				5/17	0945	260	17.0	9.10	93.5	0.84	1,180	560	7.7	0	54.4	15
				5/25	1050	129	17.5	9.20	95.5	1.31	913	680	8.0	0	67.6	10
				6/9	0915	138	17.0	9.20	94.5	0.81	604	820	7.9	0	77.8	13
				6/14	1005	129	20.5	8.04	87.5	0.91	634	1,200	8.2	3.8	84.2	11
				6/17	0835	98	19.5	8.32	90.0	0.78	413	1,100	8.1	2.2	82.4	11
				6/21	1040	70	20.0	8.60	94.0	0.84	318	1,600	8.1	0	96.2	6
	S-2			5/16	1235	295	18.5	9.00	95.5	5.03	8,012	3,000	7.6	0	51.6	27
				5/17	0915	280	19.0	7.76	83.0	5.50	8,316	2,200	7.2	0	47.6	16
				5/25	1100	149	21.5	7.35	82.5	12.46	10,025	10,000	7.6	0	76.5	17
				6/9	0855	158	R 20.5	R 8.40	R 93.0							
							L 20.5	L 8.07	L 89.0	5.53	4,718	1,500	7.6	0	66.6	17
				6/14	1030	149	R 24.0	R 6.98	R 82.0							
							L 24.5	L 7.12	L 84.0	11.52	9,269	19,000	7.7	0	72.4	36
				6/17	0825	108	R 23.0	R 7.17	R 82.5							
							L 24.0	L 6.94	L 81.0	6.14	3,581	3,300	7.6	0	70.0	16
				6/21	1105	90	R 25.0	R 5.20	R 62.0							
							L 25.0	L 6.54	L 73.0	12.52	6,085	5,500	7.6	0	77.4	27
	S-3			5/16	1315	297	18.0	8.70	91.0	2.21	3,544	21,000	7.5	0	48.4	11
				5/17	0845	282	18.0	7.92	83.0	1.84	2,802	12,000	7.5	0	49.6	15
				5/25	1130	151	21.5	-	-	3.39	2,764	11,000	7.6	0	67.6	13
				6/9	0840	160	19.5	5.73	62.0	3.28	2,834	100,000	7.6	0	73.4	16
				6/14	1050	151	23.5	5.48	63.0	2.91	2,373	150,000	7.6	0	77.4	18
				6/17	0800	110	23.0	4.17	48.0	2.92	1,734	190,000	7.7	0	79.2	19
				6/21	1110	72	23.0	4.64	53.0	4.89	1,901	280,000	7.6	0	78.6	22
	S-4			5/18	0900	328	20.0	8.59	94.0	1.24	2,196	950	7.9	0	56.0	13
				5/19	1215	293	21.5	9.51	107.0	1.66	2,626	370	8.0	0	59.8	12
				5/27	1000	198	21.0	8.22	101.0	1.52	1,625	1,800	7.8	0	76.2	16
				5/31	1200	690	20.5	8.59	95.0	1.70	6,334	6,400	7.6	0	42.2	16
				6/10	0840	255	20.5	9.28	102.0	1.76	2,424	2,700	8.0	0	78.0	14
				6/15	1125	300	25.0	9.09	109.0	1.79	2,900	3,300	8.0	0	71.4	19
				6/20	0840	158	23.5	8.79	102.0	1.94	1,655	530	8.2	0	83.8	14
Middle River	S-5a			5/16	1010	161	16.0	9.80	98.5	1.00	869	380	8.3	4.2	138.0	6
				5/17	1130	140	19.5	9.80	106.0	2.15	1,625	390	8.4	10.2	138.4	6
				5/25	0930	88	18.0	8.77	92.0	1.67	794	180	8.3	10.0	179.0	6
				6/9	1015	98	17.5	9.39	97.0	0.84	445	130	8.3	8.0	165.0	6
				6/14	0910	91	20.0	8.48	92.5	1.75	860	2,800	8.3	4.0	171.4	6
				6/17	0925	85	20.5	8.58	95.0	0.96	441	800	8.3	7.8	164.2	10
				6/21	0920	73	20.5	8.60	95.0	1.26	497	350	8.3	4.4	173.2	7

Stream Survey Data (Continued)

Grab Samples
May - June 1960

Shenandoah River	Station No.*	Mileage to Mouth	Mileage to Potomac	1960 Date	Time	Flow, cfs	Temp. °C	D.O. ppm	D.O. % Saturation	BOD ppm	BOD lbs/day	Coliform per 100 ml	pH	Alkalinity, ppm Phen.	Alkalinity, ppm Total	Color Co-Pt., Units
Lewis Creek	S-5			5/16	1050	48.5	17.0	7.70	79.0	4.97	1,302	7,000	8.1	0	256.8	11
				5/17	1010	42.0	18.0	7.91	83.0	4.23	959	5,200	8.0	0	248.4	12
				5/25	0950	26.3	17.5	7.83	81.5	4.03	572	28,000	8.2	7.0	253.8	8
				6/9	0950	29.5	17.5	8.11	84.0	2.97	473	34,000	8.1	4.0	256.0	9
				6/14	0930	27.3	19.5	6.78	73.5	5.14	758	260,000	8.2	2.6	241.4	17
				6/17	0905	26.5	19.0	6.05	65.0	5.22	747	43,000	8.1	11.2	248.4	9
				6/21	0940	22.0	18.5	6.35	67.5	4.69	557	47,000	8.1	0	243.8	11
Middle River	S-6			5/18	0830	368	20.5	7.41	82.0	0.49	974	1,000	8.2	0	161.0	8
				5/19	1240	322	22.5	8.79	100.0	0.84	1,461	420	8.3	14.0	164.0	8
				5/27	0825	275	21.0	7.27	81.0	1.35	2,005	2,000	8.2	0	183.4	13
				5/31	1230	689	20.0	8.21	89.5	0.78	2,902	5,700	8.1	0	125.0	11
				6/10	0810	265	20.0	7.99	87.0	0.60	859	730	8.2	8.0	180.0	7
				6/15	1155	397	23.5	8.01	93.0	1.77	3,795	11,000	8.2	9.0	171.2	11
				6/20	0805	209	23.0	6.90	79.5	0.84	948	1,100	8.2	6.2	184.0	9
North River	S-9			5/16	0935	512	14.5	9.95	98.5	1.17	3,235	560	7.9	0	53.4	6
				5/17	1200	448	18.0	10.10	106.0	3.20	7,741	880	8.0	0	58.6	6
				5/25	0905	211	18.0	8.19	85.5	1.36	1,550	14,000	8.1	0	92.4	6
				6/9	1035	478	17.0	9.61	98.5	1.15	2,968	3,200	7.8	0	58.4	7
				6/14	0850	262	20.0	8.02	88.5	1.66	2,349	31,000	8.2	0	90.4	6
				6/17	0945	214	20.5	8.51	94.0	1.19	1,375	7,000	8.1	2.0	97.6	6
				6/21	0900	168	19.5	8.30	90.0	1.38	1,252	32,000	8.1	0	110.0	8
Blacks Run	S-7			5/16	0815	30.7	15.0	8.05	79.5	4.48	743	110,000	7.9	0	235.8	16
				5/17	1310	27.0	20.5	8.81	97.5	5.48	799	45,000	8.0	0	223.0	20
				5/25	0810	12.7	16.5	3.80	38.5	10.50	720	190,000	8.0	0	220.0	30
				6/9	1130	28.8	20.0	7.40	81.0	11.10	1,726	110,000	8.0	0	225.4	19
				6/14	0800	15.6	19.5	3.30	35.5	13.76	1,159	140,000	7.9	0	204.6	28
				6/17	1025	12.9	21.5	6.55	73.5	5.74	400	72,000	8.0	2.6	221.6	17
				6/21	0820	10.1	19.0	4.87	52.0	14.70	802	240,000	7.8	0	203.0	24
	S-8			5/16	0855	73.2	15.5	7.40	70.5	3.50	1,383	3,000	8.0	0	220.0	13
				5/17	1220	63.5	21.0	7.90	88.0	5.50	1,886	42,000	8.2	12.2	218.0	18
				5/25	0830	29.8	19.0	4.57	49.0	5.43	874	7,800	8.0	0	217.8	16
				6/9	1050	67.7	19.5	7.54	81.5	4.42	1,616	23,000	8.1	2.0	207.8	18
				6/14	0820	37.0	20.5	5.49	60.0	5.49	1,097	43,000	8.1	0	204.2	16
				6/17	0955	30.2	20.5	6.44	71.0	4.00	652	23,000	8.1	3.0	210.4	14
				6/21	0840	23.8	21.0	5.54	61.5	3.93	505	15,000	8.1	0	208.4	16
North River	S-9a			5/18	0920	978	20.0	8.50	93.0	0.75	3,961	1,300	8.2	0	119.0	8
				5/19	1155	869	21.0	9.32	104.0	1.29	6,053	240	8.3	8.0	124.4	7
				5/27	0940	560	20.5	7.83	87.0	1.40	4,385	1,800	8.2	0	174.3	12
				5/31	1145	2,058	19.0	8.78	94.0	0.60	6,668	9,100	8.0	0	75.2	9
				6/10	0900	755	20.0	9.06	99.0	0.92	3,751	620	8.2	4.2	119.0	9
				6/15	1115	894	23.0	7.22	83.0	2.08	10,041	15,000	8.2	3.0	147.0	20
				6/20	0855	470	23.5	8.21	95.5	1.04	2,640	700	8.4	8.0	156.0	9

Stream Survey Data (Continued)

Grab Samples
May - June 1960

Shenandoah River	Station No.*	Mileage to Mouth	Mileage to Potomac	1960 Date	Time	Flow, cfs	Temp. °C	D.O. ppm	D.O. % Saturation	BOD ppm	BOD lbs/day	Coliform per 100 ml	pH	Alkalinity, ppm Phen.	Alkalinity, ppm Total	Color Co-Pt., Units
South Fork	S-10			5/18	1030	1,306	20.0	8.35	91.0	1.37	9,962	1,300	8.1	0	100.6	10
				5/19	1405	1,162	20.5	8.50	94.0	1.03	6,463	550	8.2	6.0	105.8	10
				5/27	1025	778	20.5	8.08	89.0	1.32	5,546	1,400	8.1	0	135.2	11
				5/31	1100	2,748	19.0	8.80	94.5	1.10	16,323	5,900	8.0	0	69.4	11
				6/10	0950	1,010	20.5	8.73	96.5	1.39	7,581	1,100	8.1	0	109.0	11
				6/15	1020	1,194	23.0	7.68	88.5	1.79	11,541	17,000	8.1	0	122.6	22
				6/20	0945	628	24.0	7.75	90.5	1.14	3,866	900	8.3	3.0	138.4	11
	S-11			5/18	1100	1,493	20.5	8.80	97.5	1.20	9.675	370	8.2	0	98.4	9
				5/19	1030	1,315	21.0	9.01	100.0	0.48	3,408	240	8.2	4.2	102.0	8
				5/27	1100	850	20.0	8.35	91.0	1.50	6,885	190	8.1	0	129.2	11
				5/31	1030	3,133	19.0	8.81	94.0	0.91	15,395	4,400	7.9	0	66.4	12
				6/10	1015	1,115	20.5	9.52	105.0	1.03	6,202	210	8.3	4.2	107.2	10
				6/15	1510	1,394	24.0	8.36	98.0	1.42	10,689	2,400	8.3	4.2	126.6	11
				6/20	1025	706	24.5	9.53	113.0	1.10	4,194	340	8.5	5.2	153.8	10
	S-12			5/18	1130	1,620	21.5	8.05	89.5	1.60	13,997	250,000	8.2	0	98.0	11
				5/19	1005	1,404	21.0	8.00	89.0	1.42	10,766	46,000	8.1	2.0	101.2	11
				5/27	1125	899	20.5	7.55	83.5	2.27	11,020	48,000	8.1	0	126.6	12
				5/31	0955	3,398	18.5	8.70	92.0	0.80	14,679	100,000	8.0	0	64.0	13
				6/10	1050	1,180	20.5	8.45	93.5	1.68	10,705	6,300	8.2	0	104.0	10
				6/15	0940	1,529	23.0	7.32	84.5	2.33	19,238	50,000	8.1	2.8	119.8	13
				6/20	1100	760	24.5	8.33	99.0	1.21	4,966	17,000	8.4	2.2	133.0	11
	S-13			5/18	1200	1,750	20.0	8.00	87.5	1.28	12,096	20,000	8.1	0	93.8	10
				5/19	0935	1,502	20.0	7.59	83.0	1.19	9,652	7,400	8.0	0	96.0	11
				5/27	1230	948	21.0	6.13	68.5	2.07	[illegible]	22,000	8.0	0	124.4	13
				5/31	0925	3,668	17.5	8.60	89.0	0.95	[illegible]	91,000	7.9	0	61.6	13
				6/10	1120	1,250	21.0	7.88	88.0	2.10	14,175	4,900	8.1	0	102.2	12
				6/15	0920	1,669	23.0	6.19	71.0	1.97	17,755	13,000	8.0	0	109.0	18
				6/20	1150	814	25.0	7.21	86.0	2.00	8,791	1,800	8.3	2.2	127.0	9
Hawksbill Creek	S-14			5/18	0845	23.2	15.0	9.41	82.0	1.30	163	6,900	7.7	0	24.2	14
				5/19	1140	20.6	18.0	9.55	100.0	1.23	137	1,500	7.6	0	26.2	9
				5/27	0835	13.8	17.0	8.78	90.0	0.79	59	8,400	7.4	0	38.6	11
				5/31	1215	48.5	19.0	9.06	97.0	0.92	241	1,200	7.6	0	26.0	11
				6/10	0755	17.9	16.0	9.21	92.5	1.00	97	2,600	7.7	0	43.0	7
				6/15	1140	18.0	21.0	8.62	96.0	1.19	116	3,000	7.7	0	39.0	19
				6/20	0830	11.1	19.5	8.34	90.0	0.34	20	[illegible]	7.7	0	52.2	11
	S-15			5/18	0905	75.0	16.0	8.59	86.5	1.52	616	26,000	7.8	0	46.0	20
				5/19	1115	56.5	17.0	9.25	95.0	1.96	704	2,600	7.8	0	49.6	11
				5/27	0900	44.5	17.5	7.19	74.5	1.72	413	11,000	7.8	0	76.0	12
				5/31	1135	158.0	17.0	9.49	97.5	1.04	887	6,200	7.9	0	43.6	7
				6/10	0810	58.0	17.0	7.01	72.0	2.39	749	5,400	7.7	0	79.0	20
				6/15	1120	68.5	20.0	6.92	75.5	4.02	1,487	63,000	7.6	0	55.4	34
				6/20	0915	36.0	20.5	8.63	95.5	1.48	288	7,200	8.0	0	88.2	11

Stream Survey Data (Continued)

Grab Samples
May - June 1960

Shenandoah River	Station No.*	Mileage to Mouth	Mileage to Potomac	1960 Date	Time	Flow, cfs	Temp. °C	D.O. ppm	D.O. % Saturation	BOD ppm	BOD lbs/day	Coliform per 100 ml	pH	Alkalinity, ppm Phen.	Alkalinity, ppm Total	Color Co-Pt., Units
South Fork	S-16			5/18	1300	2,030	21.0	8.50	94.5	1.00	10,962	1,500	8.2	0	90.0	12
				5/19	0845	1,717	20.0	8.40	92.0	1.31	12,146	490	8.1	2.0	90.4	11
				5/27	1320	1,058	22.5	9.08	104.0	1.44	8,227	120	8.1	3.6	118.0	14
				5/31	0830	4,248	18.0	9.00	94.5	0.92	21,104	4,000	7.9	0	54.8	16
				6/10	1215	1,405	23.0	9.01	104.0	2.29	17,374	330	9.1	0	90.6	10
				6/15	0820	1,969	25.0	7.93	95.0	1.49	15,843	3,200	8.5	8.0	113.4	11
				6/20	1320	933	28.5	11.73	149.0	3.00	15,115	60	9.1	11.6	120.0	18
	S-17			5/18	0930	2,110	18.0	8.45	88.5	1.34	15,268	5,600	8.1	0	80.0	13
				5/19	1050	1,782	20.0	8.95	97.5	1.53	14,723	350	8.2	4.0	86.0	10
				5/27	0915	1,088	20.5	8.20	90.5	1.29	7,579	290	8.1	3.6	118.0	13
				5/31	1120	4,388	17.5	8.99	93.5	1.18	27,960	3,900	7.9	0	54.0	16
				6/10	0825	1,440	20.0	8.42	92.0	1.47	11,431	700	8.1	0	84.6	13
				6/15	1105	2,044	24.0	8.95	105.0	1.62	17,881	4,100	8.6	6.4	104.8	18
				6/20	0935	963	23.5	8.90	104.0	1.85	9,620	300	8.4	5.8	121.4	17
	S-18			5/18	1015	2,275	19.0	8.40	90.0	1.04	12,776	160	8.1	0	84.0	11
				5/19	1005	1,907	20.0	8.76	95.5	1.51	15,549	110	8.1	0	84.2	14
				5/27	0940	1,153	21.5	8.61	97.0	1.33	8,281	220	8.2	0	111.2	12
				5/31	1050	4,748	18.0	8.87	93.0	1.10	28,203	560	7.9	0	50.2	17
				6/10	0850	1,535	21.0	8.62	96.0	1.18	9.781	260	8.1	0	79.8	12
				6/15	1025	2,234	23.0	7.90	91.0	1.61	19,422	2,300	8.3	2.2	90.0	22
				6/20	1000	1,033	25.5	9.83	118.0	2.68	14,950	200	8.8	4.6	126.4	19
	S-19			5/18	1055	2,478	18.0	8.35	87.5	0.87	11,642	230	8.2	0	82.0	12
				5/19	0935	2,058	19.0	8.64	92.5	1.27	14,114	180	8.1	2.0	84.6	11
				5/27	1010	1,227	21.0	8.62	96.0	1.96	12,987	370	8.4	3.6	108.0	12
				5/31	1015	5,168	17.5	8.77	91.0	1.49	41,582	2,200	7.9	0	47.8	19
				6/10	0920	1,643	20.5	8.81	97.5	0.81	7,186	380	8.1	0	76.2	11
				6/15	0950	2,450	22.0	7.63	87.0	1.51	19,977	6,500	7.9	0	71.8	37
				6/20	1040	1,117	25.5	10.25	124.0	3.58	21,594	270	9.0	10.0	109.6	21
	S-20			5/18	1125	2,478	19.0	8.65	93.0	0.97	12,980	460	8.2	0	80.2	11
				5/19	0900	2,058	19.0	8.52	91.0	1.40	15,558	500	8.1	0	83.8	12
				5/27	1030	1,227	21.0	8.39	93.5	2.80	18,552	700	8.3	0	103.6	17
				5/31	0920	5,168	17.0	8.71	89.5	1.33	37,116	2,500	7.9	0	48.0	21
				6/10	0945	1,643	21.5	8.69	97.5	2.14	18,986	870	8.2	0	74.6	12
				6/15	0920	2,450	21.5	7.40	83.0	1.05	13,892	8,700	7.9	0	69.4	36
				6/20	1100	1,117	26.0	10.55	128.0	4.02	24,248	160	9.1	9.4	106.2	22

Stream Survey Data (Continued)

Grab Samples
May - June 1960

Shenandoah River	Station No.	Mileage to Mouth	Mileage to Potomac	1960 Date	Time	Flow, cfs	Temp. °C	D.O. ppm	D.O. % Saturation	BOD ppm	BOD lbs/day	Coliform per 100 ml	pH	Alkalinity, ppm Phen.	Alkalinity, ppm Total	Color Co-Pt., Units
North Fork	N-1			5/16	0915	269	15.5	9.91	99.0	0.68	1202	65	7.6	0	18.6	7
				5/17	1320	229	19.0	9.75	104.0	0.71	1155	12	7.5	0	20.0	7
				5/25	0830	112	17.0	8.85	91.0	1.00	739	390	7.4	0	26.2	6
				6/9	1150	112	20.0	9.70	106.0	1.68	1236	55	7.4	0	23.2	6
				6/14	1125	108	22.0	8.82	99.5	0.30	213	2,400	7.8	0	29.0	6
				6/17	0810	59	21.0	8.20	91.0	0.22	100	740	7.7	0	28.8	5
				6/21	0815	35	21.5	8.10	91.0	0.49	113	420	7.7	0	34.0	6
	N-2			5/16	0950	495	16.5	9.71	98.5	1.88	5,025	1,500	7.9	0	64.0	7
				5/17	1250	445	19.5	9.70	105.0	1.80	4,325	1,300	8.2	0	69.2	6
				5/25	0900	295	19.5	7.73	84.0	2.05	3,155	34,000	8.0	0	91.6	9
				6/9	1125	301	20.5	9.10	100.0	1.42	2,308	5,100	8.2	3.0	93.2	7
				6/14	1045	189	23.0	7.59	88.0	2.14	2,184	57,000	8.2	0	110.0	8
				6/17	0845	366	23.0	7.02	81.0	1.18	2,332	110,000	8.1	0	100.6	7
				6/21	0845	177	22.0	6.55	75.0	1.95	1,864	190,000	8.0	0	133.6	6
	N-3			5/16	1040	685	17.0	9.60	99.5	0.70	2,589	1,100	7.9	0	80.4	7
				5/17	1210	625	20.0	9.49	104.0	0.81	2,734	1,700	[illegible]	0	66.4	8
				5/25	0940	415	19.5	8.30	90.0	1.58	3,541	3,300	8.1	2.2	114.2	9
				6/9	1100	376	20.5	9.01	99.5	1.26	2,558	3,500	8.1	1.8	116.2	10
				6/14	1015	269	23.0	8.33	96.0	0.39	1,293	6,000	8.2	2.0	141.8	9
				6/17	0915	546	23.5	7.40	86.0	1.26	3,715	17,000	8.2	0.8	118.4	14
				6/21	0915	267	23.0	7.93	91.5	0.92	1,326	17,000	8.2	0	144.4	11
	N-4			5/16	1135	880	17.0	10.40	107.0	1.30	6,178	200	8.1	0	102.4	9
				5/17	1115	815	18.0	10.10	106.0	1.14	5,017	110	8.3	0	106.0	8
				5/25	1025	545	21.0	8.19	91.0	1.24	3,649	390	8.2	1.0	120.0	14
				6/9	0945	496	22.5	8.19	93.5	0.78	2,089	270	8.4	1.8	115.6	11
				6/14	0935	354	23.0	7.25	83.5	1.94	3,709	5,100	8.3	3.0	135.8	16
				6/17	1000	736	22.0	8.27	93.5	0.57	2,663	2,000	8.2	0.8	92.2	19
				6/21	1010	361	23.0	7.90	91.0	3.50	6,823	1,100	8.2	0	130.0	13
	N-5			5/16	1210	1,005	19.0	10.80	115.0	1.12	6,078	2,400	8.3	4.4	105.6	9
				5/17	1030	932	18.0	9.58	100.0	0.88	4,429	4,200	8.3	4.0	117.8	11
				5/25	1105	630	22.0	10.11	114.0	1.85	6,294	7,200	8.5	8.0	120.0	13
				6/9	0910	571	21.5	8.63	97.0	0.96	2,960	2,500	8.3	2.2	110.8	14
				6/14	0910	406	23.5	6.80	78.0	1.85	4,056	11,000	8.2	1.2	127.5	19
				6/17	1035	855	24.0	7.61	89.0	1.24	5,725	11,000	8.1	0	98.0	33
				6/21	1120	418	23.5	9.40	109.0	1.12	2,528	13,000	8.3	1.0	125.0	14
Passage Creek	N-7			5/20	0840	53.5	19.0	8.91	95.0	0.52	150	320	7.5	0	24.2	13
				5/23	1425	59.5	20.0	8.66	94.5	1.05	337	900	7.4	0	23.6	21
				6/2	0840	77.0	18.0	9.22	97.0	0.67	279	520	7.4	0	20.0	14
				6/7	1415	57.0	22.0	8.91	101.0	0.60	185	260	7.4	0	21.2	14
				6/13	0820	30.7	19.5	8.70	94.0	0.69	114	310	7.4	0	31.6	14
				6/16	0825	112.0	18.0	9.00	94.5	0.78	472	1,700	7.3	0	17.6	23
				6/22	1135	23.0	19.0	9.35	100.0	0.63	78	340	7.4	0	26.0	16

Stream Survey Data (Continued)

Grab Samples
May - June 1960

Shenandoah	Station No.*	Mileage to Mouth	Mileage to Potomac	1960 Date	Time	Flow, cfs	Temp. °C	D.O. ppm	D.O. % Saturation	BOD ppm	BOD lbs/day	Coliform per 100 ml	pH	Alkalinity, ppm Phen.	Alkalinity, ppm Total	Color Co-Pt., Units
North Fork	N-6			5/16	1250	1,230	19.0	9.75	104.0	0.91	6,044	85	8.2	2.2	92.4	8
				5/17	0950	1,145	18.5	8.82	93.5	0.92	5,688	1,300	8.2	0	94.4	12
				5/25	1135	780	21.5	8.50	95.0	1.16	4,886	2,500	8.3	2.0	102.0	14
				6/9	0840	706	21.0	7.78	86.5	1.15	4,384	3,200	8.2	2.0	99.8	13
				6/14	0815	502	22.0	7.10	80.0	2.57	6,967	45,000	-	0	71.6	43
				6/17	1105	1,066	23.0	7.80	90.0	0.95	5,469	4,200	8.0	0	73.8	32
				6/21	1150	524	23.5	8.50	99.0	1.00	2,830	1,900	8.3	1.2	111.0	11
Main Stem	M-1			5/20	0930	2,976	22.5	8.81	101.0	0.89	13,822	320	8.4	6.0	88.0	12
				5/23	1345	2,829	23.0	8.18	94.0	2.08	31,775	3,100	8.1	0	88.2	18
				6/2	0910	4,477	20.5	8.78	97.0	1.08	26,110	2,800	7.9	0	65.4	13
				6/7	1340	3,782	24.0	8.02	94.0	1.80	36,761	2,900	7.8	0	73.2	32
				6/13	0915	1,324	23.5	8.43	98.0	1.68	16,547	400	8.6	5.0	101.2	13
				6/16	0925	4,169	22.0	8.40	95.0	1.95	43,900	21,000	7.9	0	65.8	28
				6/22	1100	1,684	24.0	10.45	123.0	4.04	36,738	2,900	8.8	8.0	102.0	27
	M-2			5/20	1005	3,047	22.0	8.90	100.0	0.90	14,808	80	8.3	4.6	85.8	11
				5/23	1300	3,191	22.0	7.72	88.5	1.90	32,739	1,300	8.0	0	82.2	21
				6/2	0950	5,050	20.5	8.38	92.5	0.98	26,725	2,100	7.9	0	64.4	19
				6/7	1300	4,310	24.5	8.28	98.0	1.30	30,256	1,000	8.1	0	99.6	12
				6/13	1000	1,990	24.0	9.28	109.0	2.31	24,899	170	8.5	2.8	95.0	14
				6/16	1010	5,414	22.5	7.31	83.5	2.12	61,979	8,100	7.9	0	84.0	44
				6/22	1025	2,364	22.5	10.70	122.0	3.18	40,595	130	8.8	11.4	89.2	26
	M-3			5/20	1100	3,167	22.0	9.00	102.0	0.93	15,905	100	8.2	2.0	88.4	12
				5/23	1115	3,411	22.0	7.04	80.0	2.40	44,207	700	7.9	0	79.6	32
				6/2	1030	5,400	20.5	8.47	93.5	0.93	27,119	1,600	7.9	0	62.2	19
				6/7	1335	4,620	24.5	7.97	94.0	0.83	20,707	760	8.0	0	96.6	13
				6/13	1040	2,102	23.5	9.38	109.0	3.01	34,166	190	8.8	3.8	94.0	16
				6/16	1100	6,184	22.0	7.23	82.0	2.20	73,466	12,000	7.9	0	58.4	48
				6/22	0850	2,784	22.5	9.56	109.0	3.50	52,617	140	8.6	5.0	95.0	27
	M-4			5/20	1125	3,220	22.5	9.30	106.0	0.84	14,606	200	8.4	12.6	94.2	13
				5/23	1035	3,511	23.0	8.31	96.0	2.83	53,655	1,400	8.1	0	90.4	17
				6/2	1120	5,580	22.0	8.90	101.0	0.85	25,612	1,700	8.0	0	64.0	17
				6/7	1035	4,790	25.0	8.40	100.0	1.81	46,817	580	8.1	0	92.6	17
				6/13	1115	2,153	23.0	9.72	112.0	2.75	31,972	230	9.0	8.0	92.6	20
				6/16	1130	6,564	23.0	8.08	93.5	2.13	75,499	13,000	8.0	0	74.0	47
				6/22	0830	2,984	22.0	8.98	101.0	3.58	57,687	290	8.6	3.6	91.8	

Stream Survey Data (Continued)

Grab Samples
May - June 1960

Shenandoah River	Station No.*	Mileage to Mouth	Mileage to Potomac	1960 Date	Time	Flow, cfs	Temp. °C	D.O. ppm	D.O. % Saturation	BOD ppm	BOD lbs/day	Coliform per 100 ml	pH	Alkalinity, ppm Phen.	Alkalinity, ppm Total	Color Co-Pt., Units
Main Stem	P-1			5/20	1150	10,800	21.5	9.10	102.0	0.85	49,572	540	8.1	0	60.0	13
				5/23	1015	11,350	21.0	8.50	94.5	1.30	79,677	950	7.9	0	65.8	11
				6/2	1135	20,300	20.5	9.21	102.0	0.78	85,503	1,800	7.8	0	51.6	20
				6/7	1015	18,200	23.0	8.20	95.0	1.21	118,919	3,100	7.8	0	62.2	38
				6/13	1130	6,280	23.0	9.71	112.0	2.99	101,397	3,000	8.7	3.8	84.0	17
				6/16	1145	23,200	24.5	8.11	96.0	2.07	259,330	21,000	7.9	0	77.8	37
				6/22	0820	6,600	21.0	8.25	92.0	0.98	34,927	1,200	7.9	0	67.8	24
	P-2			5/20	1230	11,184	22.0	8.95	101.0	1.00	60,394	130	8.2	2.0	59.0	12
				5/23	0935	11,728	21.0	7.90	88.0	1.80	113,496	540	7.8	0	68.2	16
				6/2	1230	21,014	21.0	8.90	99.0	1.06	120,284	2,300	7.9	0	54.4	25
				6/7	0930	18,850	23.0	7.90	91.0	1.15	117,059	2,600	7.8	0	65.8	27
				6/13	1500	6,474	25.0	9.47	113.0	2.56	89,497	800	8.7	3.0	84.2	24
				6/16	1225	23,873	24.0	7.81	91.5	1.37	176,612	22,000	7.9	0	73.8	38
				6/22	0750	6,807	21.5	7.96	89.0	1.40	51,461	990	7.9	0	80.2	27

PART V

APPENDIX II

Stream Survey Data - Composite Samples

Stream Survey Data

Composite Samples

Station S-1

1960 Date	5/24	Time	6/1	Time	6/6	Time
Stream Flow, cfs	140		290		169	
Temp. °C	15.5	0800	17.5	0800	19.0	0825
	17.0	1000	17.5	1015	19.5	1015
	18.0	1200	19.0	1200	20.5	1200
	18.0	1400	19.5	1350	21.0	1400
D.O., ppm	9.20	0800	8.99	0800	8.60	0825
	9.40	1000	9.08	1015	8.70	1015
	9.50	1200	9.05	1200	8.70	1200
	9.45	1400	8.91	1350	8.80	1400
D.O., % Sat.	87.5	0800	93.0	0800	92.0	0825
	96.5	1000	94.0	1015	94.0	1015
	99.5	1200	96.5	1200	96.5	1200
	99.0	1400	96.5	1350	98.0	1400
Coliforms/100 ml	580	0800	1,500	0800	970	0825
	480	1000	1,300	1015	1,100	1015
	350	1200	980	1200	740	1200
	150	1400	780	1350	620	1400
5-day BOD						
ppm	1.22		0.91		0.93	
lbs/day	920		1,420		850	
Chem. O_2 Demand						
ppm	6.30		1.21		4.27	
lbs/day	4,760		1,900		3,900	
pH	8.3		7.6		7.9	
Alkalinity, ppm						
Phen.	2.0		0		0	
Total	74.2		53.6		78.2	
Color, Co-pt Units	4		13		12	
Kjeldahl - N, ppm	0.24		0.22		0.22	
Nitrite - N, ppm	0.003		0.0015		0.002	
Nitrate - N, ppm	0.32		0.31		0.41	
Total Solids, ppm	121		100		103	
Dis. Solids, ppm	97		61		85	

Stream Survey Data (Continued)

Composite Samples

Station S-3

1960 Date	5/24	Time	6/1	Time	6/6	Time
Stream Flow, cfs	162		312		191	
Temp. °C	18.5	0820	18.0	0815	21.5	0835
	19.5	1045	19.0	1045	22.5	1055
	21.0	1245	20.5	1235	22.5	1230
	22.0	1430	21.0	1415	23.5	1410
D.O., ppm	5.50	0820	7.41	0815	6.21	0835
	6.49	1045	7.74	1045	7.03	1055
	7.22	1245	7.81	1235	7.13	1230
	7.40	1430	7.46	1415	7.01	1410
D.O., % Sat.	58.0	0820	78.0	0815	69.5	0835
	70.0	1045	83.0	1045	80.0	1055
	80.5	1245	86.0	1235	81.5	1230
	83.5	1430	83.0	1415	81.5	1410
Coliforms/100 ml	5,000	0820	11,000	0815	6,400	0835
	5,700	1045	18,000	1045	9,600	1055
	15,000	1245	42,000	1235	15,000	1230
	10,000	1430	37,000	1415	26,000	1410
5-day BOD						
ppm	3.45		2.60		2.55	
lbs/day	3,200		4,350		2,620	
Chem. O_2 Demand						
ppm	16.30		8.55		9.18	
lbs/day	14,300		14,400		9,500	
pH	7.8		7.3		7.5	
Alkalinity, ppm						
Phen.	0		0		0	
Total	67.0		49.4		60.2	
Color, Co-pt, Units	13		12		16	
Kjeldahl - N, ppm	1.02		0.72		0.94	
Nitrite - N, ppm	0.038		0.007		0.027	
Nitrate - N, ppm	0.28		0.38		0.46	
Total Solids, ppm	149		117		119	
Dis. Solids, ppm	144		80		105	

Stream Survey Data (Continued)

Composite Samples

Station S-11

1960 Date	5/24	Time	6/1	Time	6/6	Time
Stream Flow, cfs	910		2,250		2,280	
Temp. °C	20.0	0835	18.0	0835	21.0	0830
	21.0	1030	19.0	1030	22.0	1030
	22.0	1230	19.5	1225	22.5	1225
	22.5	1437	20.5	1427	22.5	1425
D.O., ppm	8.70	0835	8.91	0835	8.51	0830
	9.47	1030	8.96	1030	8.71	1030
	9.90	1230	8.92	1225	8.61	1225
	8.89	1437	8.92	1427	8.65	1425
D.O., % Sat.	95.0	0835	93.5	0835	95.0	0830
	105.0	1030	96.0	1030	98.5	1030
	112.0	1230	97.0	1225	98.5	1225
	101.0	1437	98.5	1427	99.0	1425
Coliforms/100 ml	130	0835	2,300	0835	2,100	0830
	25	1030	1,700	1030	1,800	1030
	33	1230	1,900	1225	1,500	1225
	29	1437	1,700	1427	1,700	1425
5-day BOD						
ppm	0.85		0.72		0.86	
lbs/day	4,160		8,750		10,060	
Chem. O_2 Demand						
ppm	5.58		1.85		5.82	
lbs/day	27,500		22,500		71,800	
pH	8.3		8.0		7.9	
Alkalinity, ppm						
Phen.	3.8		0		0	
Total	119.8		77.8		67.8	
Color, Co-pt Units	9		9		11	
Kjeldahl - N, ppm	0.31		0.34		0.30	
Nitrite - N, ppm	0.016		0.005		0.007	
Nitrate - N, ppm	0.57		0.54		0.46	
Total Solids, ppm	174		153		116	
Dis. Solids, ppm	155		99		84	

Stream Survey Data (Continued)

Composite Samples

Station S-12

1960 Date	5/24	Time	6/1	Time	6/6	Time
Stream Flow, cfs	960		2,380		2,400	
Temp. °C	20.0	0857	18.0	0810	20.0	0805
	21.0	1055	18.5	1005	21.0	1005
	21.0	1255	19.0	1200	21.5	1200
	22.0	1455	20.0	1400	22.0	1400
D.O., ppm	7.51	0857	8.49	0810	8.32	0805
	8.12	1055	8.54	1005	8.30	1005
	8.58	1255	8.61	1200	8.48	1200
	10.01	1455	8.89	1400	8.36	1400
D.O., % Sat.	82.0	0857	89.0	0810	91.0	0805
	90.5	1055	90.5	1005	92.5	1005
	95.5	1255	92.0	1200	95.0	1200
	113.0	1455	97.0	1400	94.5	1400
Coliforms/100 ml	49,000	0857	29,000	0810	29,000	0805
	49,000	1055	41,000	1005	22,000	1005
	26,000	1255	50,000	1200	32,000	1200
	26,000	1455	39,000	1400	40,000	1400
5-day BOD						
ppm	2.58		1,08		1.12	
lbs/day	13,400		12,900		13,000	
Chem. O_2 Demand						
ppm	9.78		3.79		9.60	
lbs/day	50,700		48,800		124,000	
pH	8.3		7.9		7.9	
Alkalinity, ppm						
Phen.	4.0		0		0	
Total	119.0		74.6		64.0	
Color, Co-pt Units	10		12		14	
Kjeldahl - N, ppm	0.73		0.58		0.44	
Nitrite - N, ppm	0.016		0.004		0.007	
Nitrate - N, ppm	0.52		0.48		0.48	
Total Solids, ppm	176		142		120	
Dis. Solids, ppm	159		96		83	

Stream Survey Data (Continued)

Composite Samples

Station S-19

1960 Date	6/2	Time	6/3	Time	6/8	Time
Stream Flow, cfs	2,947		2,660		2,198	
Temp. °C	20.0	0820	21.0	0810	21.0	0825
	20.5	1010	23.0	1000	21.5	1005
	21.5	1200	23.5	1155	22.0	1150
	22.0	1350	24.0	1350	22.5	1345
D.O., ppm	8.20	0820	7.90	0810	7.95	0825
	8.35	1010	8.10	1000	8.30	1005
	8.55	1200	8.20	1155	8.45	1150
	8.70	1350	8.35	1350	8.60	1345
D.O., % Sat.	89.5	0820	88.0	0810	88.5	0825
	93.5	1010	93.5	1000	93.0	1005
	96.0	1200	95.5	1155	95.5	1150
	96.0	1350	98.0	1350	98.5	1345
Coliforms/100 ml	1,600	0820	1,200	0810	1,000	0825
	900	1010	1,000	1000	660	1005
	1,300	1200	1,100	1155	810	1150
	960	1350	850	1350	620	1345
5-day BOD						
ppm	0.89		1.07		0.91	
lbs/day	14,100		15,400		10,800	
Chem. O_2 Demand						
ppm	11.60		9.14		7.22	
lbs/day	186,000		130,000		85,500	
pH	7.9		8.0		7.8	
Alkalinity, ppm						
Phen.	0		0		0	
Total	64.6		68.8		61.0	
Color, Co-pt, Units	13		13		13	
Kjeldahl - N, ppm	0.46		0.32		0.41	
Nitrite - N, ppm	0.007		0.006		0.010	
Nitrate - N, ppm	0.44		0.51		0.46	
Total Solids, ppm	125		136		129	
Dis. Solids, ppm	87		96		88	

Stream Survey Data (Continued)

Composite Samples

Station S-20

1960 Date	6/2			Time	6/3			Time	6/8			Time
Stream Flow, cfs		2,947				2,660				2,198		
	R.	M.	L.		R.	M.	L.		R.	M.	L.	
Temp. °C	20.0	20.0	19.5	0845	21.0	21.0	21.0	0840	21.0	21.0	21.0	0845
	20.5	21.0	20.5	1010	22.0	22.5	22.0	1015	21.0	21.5	22.0	1035
	21.0	21.0	21.5	1200	23.5	23.5	23.5	1205	22.5	22.5	22.5	1205
	21.5	22.0	22.0	1415	24.0	24.0	24.0	1405	23.0	23.5	23.5	1400
D.O., ppm	8.50	8.45	8.30	0845	7.90	8.00	7.80	0840	7.95	8.20	8.20	0845
	8.60	8.55	8.40	1010	8.30	8.25	8.05	1015	7.90	8.40	8.45	1035
	8.75	8.75	8.45	1200	8.40	8.50	8.15	1205	8.30	8.60	8.60	1205
	8.75	8.80	8.60	1415	8.40	8.40	8.05	1405	8.40	8.75	8.70	1400
D.O., % Sat.	93.0	92.5	90.0	0845	88.0	89.0	87.0	0840	88.5	91.0	91.0	0845
	95.0	95.0	93.0	1010	94.0	94.5	91.0	1015	88.0	94.5	95.5	1035
	97.5	97.5	95.0	1200	98.0	99.0	95.0	1205	95.0	98.5	98.5	1205
	97.5	99.5	97.0	1415	97.5	97.0	94.5	1405	97.0	101.0	101.0	1400
Coliforms/100 ml		2,000		0845		2,000		0840		710		0845
		1,100		1010		1,300		1015		860		1035
		830		1200		1,600		1205		670		1205
		630		1415		1,000		1405		1,100		1400
5-day BOD												
ppm		1.46				1.60				1.33		
lbs/day		23,200				23,000				15,800		
Chem. O_2 Demand												
ppm		14.40				10.60				9.62		
lbs/day		228,000				152,000				114,000		
pH		7.9				8.0				7.9		
Alkalinity, ppm												
Phen.		0				0				0		
Total		55.4				69.0				62.2		
Color, Co-pt, Units		12				14				17		
Kjeldahl - N, ppm		0.63				0.46				0.70		
Nitrite - N, ppm		0.008				0.007				0.010		
Nitrate - N, ppm		0.46				0.46				0.45		
Total Solids, ppm		135				148				142		
Dis. Solids, ppm		96				108				96		

Stream Survey Data (Continued)

Composite Samples

Station M-4

1960 Date	5/26	Time	6/3	Time	6/8	Time
Stream Flow, cfs	2,650		4,800		3,850	
Temp. °C	21.0	0815	21.5	0800	23.0	0815
	22.5	1015	22.5	1000	24.0	1015
	23.0	1210	24.0	1200	25.0	1210
	23.0	1405	24.5	1400	25.5	1405
D.O., ppm	8.10	0815	8.52	0800	8.45	0815
	9.61	1015	8.75	1000	8.76	1015
	10.07	1210	8.75	1200	8.95	1210
	10.09	1400	8.71	1400	8.86	1405
D.O., % Sat.	90.0	0815	96.0	0800	99.0	0815
	110.0	1015	100.0	1000	102.0	1015
	116.0	1210	102.0	1200	106.0	1210
	117.0	1400	103.0	1400	106.0	1405
Coliforms/100 ml	300	0815	730	0800	800	0815
	260	1015	560	1000	850	1015
	120	1210	420	1200	420	1210
	30	1400	250	1400	410	1405
5-day BOD						
ppm	2.10		0.91		1.01	
lbs/day	30,000		23,000		21,000	
Chem. O_2 Demand						
ppm	10.30		10.90		7.13	
lbs/day	147,000		282,000		148,000	
pH	8.6		8.0		8.1	
Alkalinity, ppm						
Phen.	10.0		0		0	
Total	100.2		71.0		103.6	
Color, Co-Pt, Units	16		14		13	
Kjeldahl - N, ppm	0.54		0.33		0.45	
Nitrite - N, ppm	0.004		0.005		0.009	
Nitrate - N, ppm	0.38		0.50		0.72	
Total Solids, ppm	155		125		157	
Dis. Solids, ppm	135		107		138	

Stream Survey Data (Continued)

Composite Samples

Station M-4a

1960 Date	5/26	Time	6/3	Time	6/8	Time
Stream Flow, cfs	5.5		7.5		6.5	
Temp. °C	20.0	0840	21.5	0820	19.5	0840
	21.0	1035	23.5	1020	21.0	1040
	23.5	1230	25.0	1220	23.0	1235
	23.5	1430	26.0	1415	24.0	1430
D.O., ppm	7.79	0840	7.57	0820	8.10	0840
	7.81	1035	7.21	1020	7.90	1040
	7.13	1230	7.10	1220	7.50	1235
	7.01	1430	6.84	1415	7.39	1430
D.O., % Sat.	85.0	0840	85.0	0820	87.5	0840
	87.0	1035	84.0	1020	88.0	1040
	83.0	1230	85.0	1220	86.5	1235
	81.5	1430	83.0	1415	86.5	1430
Coliforms/100 ml	8,500	0840	9,300	0820	11,000	0840
	9,000	1035	6,600	1020	26,000	1040
	16,000	1230	18,000	1220	27,000	1235
	10,000	1430	16,000	1415	17,000	1430
5-day BOD						
ppm	19.86		16.99		15.63	
lbs/day	595		638		550	
Chem. O_2 Demand						
ppm	105.0		85.0		99.2	
lbs/day	3,100		3,470		3,350	
pH	8.2		8.2		8.1	
Alkalinity, ppm						
Phen.	6.0		0		0	
Total	235.0		236.0		236.4	
Color, Co-pt, Units	21		16		18	
Kjeldahl - N, ppm	1.27		1.38		1.22	
Nitrite - N, ppm	0.061		0.055		0.038	
Nitrate - N, ppm	2.10		1.95		2.25	
Total Solids, ppm	486		691		480	
Dis. Solids, ppm	405		381		375	

PART V

APPENDIX III

Composite Samples

Daily BOD Series (Average of Duplicates - ppm)

May - June, 1960

Composite Samples

Daily BOD Series (Average of Duplicates - ppm)
May - June 1960

Days at 20°C	Station S-1 5/24	Station S-1 6/1	Station S-1 6/6	Station S-3 5/24	Station S-3 6/1	Station S-3 6/6
1	0.09	0.28	0.09	1.00	0.85	0.74
2	0.65	0.49	0.38	2.05	1.62	1.22
3	0.87	0.59	0.53	2.62	1.87	1.80
5	1.22	0.91	0.92	3.45	2.60	2.55
7	1.37	1.46	1.02	4.35	3.29	3.38
9	1.58	-	1.19	6.00	3.85	4.90
Constant	$k_1 = 0.147$			$k_1 = 0.145$		

	Station S-11 5/24	Station S-11 6/1	Station S-11 6/6	Station S-12 5/24	Station S-12 6/1	Station S-12 6/6
1	0.07	0.27	0.21	0.38	0.32	0.28
2	0.38	0.30	0.40	1.44	0.43	0.55
3	0.54	0.42	0.48	2.02	0.72	0.69
5	0.85	0.72	0.86	2.58	1.08	1.12
7	1.12	0.95	1.00	2.98	1.32	1.33
9	1.28	1.28	1.19	3.57	1.75	1.48
Constant	$k_1 = 0.085$			$k_1 = 0.075$		

	Station S-19 6/2	Station S-19 6/3	Station S-19 6/8	Station S-20 6/2	Station S-20 6/3	Station S-20 6/8
1	0.10	0.24	0.25	0.48	0.70	0.51
2	0.29	0.45	0.55	0.87	0.99	0.91
3	0.53	0.95	0.69	1.06	1.20	1.04
5	0.89	1.07	0.91	1.46	1.60	1.33
7	1.08	1.18	1.23	1.92	1.69	1.61
9	1.25	1.20	1.40	2.26	2.04	1.96
Constant	$k_1 = 0.130$			$k_1 = 0.182$		

	Station M-4a 5/26	Station M-4a 6/3	Station M-4a 6/8	Station M-4 5/26	Station M-4 6/3	Station M-4 6/8
1	3.36	3.05	2.35	0.60	0.24	0.18
2	7.21	6.65	6.61	0.90	0.42	0.58
3	12.14	10.91	9.21	1.23	0.62	0.60
5	19.86	16.99	15.63	2.10	0.91	1.01
7	25.76	24.03	20.48	2.44	1.11	1.57
9	30.99	28.45	23.28	3.06	1.66	1.62
Constant	$k_1 = 0.066$			$k_1 = 0.083$		

PART V

APPENDIX IV

Sampling Data

Interstate Commission on the Potomac River Basin

1958 - 1959

Sampling Data

Interstate Commission on the Potomac River Basin
1958 - 1959

Station No.	Date	Flow cfs	Temp. °C	D.O. ppm	D.O. % Sat.	BOD_5 ppm	pH	T. Alkalinity
South River 171-176	7/17/58	73	22	8.4	95	0.6	8.3	110
	8/21	48	22	9.0	102	0.4	8.2	112
	9/2	46	13	10.2	97	0.6	7.9	104
	10/24	54	15	10.0	98	1.1	8.2	102
	11/20	33	12	10.7	100	0.8	8.1	113
	12/18	42	4	13.0	100	2.0	8.2	110
	1/23/59	182	3	12.7	97	3.1	8.3	63
	2/20	62	3	11.6	94	0.6	8.3	89
	3/20	98	9	11.4	86	0.9	8.1	70
	4/17	390	13	10.5	98	0.9	7.5	38
	5/22	67	20	8.6	94	0.9	8.2	101
	6/19	50	18	10.1	118	1.5	8.4	102
South River 171-176	7/17/58	97	27	2.5	31	16.8	7.2	84
	8/21	69	29	1.5	19	6.9	6.9	81
	9/2	67	19	4.5	47	4.0	7.3	85
	10/24	73	21	3.8	42	5.9	7.4	88
	11/20	53	20	0	0	9.2	7.5	112
	12/18	62	14	3.8	37	13.5	7.2	111
	1/23/59	201	5	11.7	91	5.0	8.0	56
	2/20	86	9	10.5	91	10.9	8.1	74
	3/20	127	15	7.3	72	9.1	7.5	60
	4/19	410	14	9.7	94	3.8	7.6	38
	5/22	91	27	2.7	35	7.6	7.3	76
	6/19	75	25	4.6	50	9.0	7.5	80
South River 171-176	7/17/58	-	25	3.6	43	2.9	7.4	103
	8/21	-	25	4.4	52	2.9	7.4	105
	9/2	-	17	5.1	52	3.9	7.5	92
	10/24	-	18	4.8	51	4.4	7.6	108
	11/20	-	15	4.9	50	4.0	7.6	112
	12/18	-	9	5.2	45	6.3	7.5	113
	1/23/59	-	5	11.3	88	3.4	7.8	49
	2/20	-	6	7.7	62	4.7	7.9	76
	3/20	-	12	7.9	73	1.9	7.4	56
	4/17	-	13	9.6	91	1.5	7.6	44
	5/22	-	24	4.2	51	6.4	7.5	85
	6/19	-	20	4.7	53	5.4	7.7	99
South River 171-152.8	7/17/58	-	25	8.0	95	0.9	8.1	103
	8/21	-	24	10.0	117	0.7	8.5	91
	9/2	-	16	11.0	110	0.7	8.4	94
	10/24	-	16	11.2	112	1.3	8.5	100
	11/20	-	14	13.8	134	1.0	8.9	99
	12/18	-	3	15.0	111	1.4	8.6	104
	1/23/59	-	6	11.4	92	3.1	7.9	63
	2/20	-	4	13.8	106	2.9	8.3	77
	3/20	-	10	11.7	103	1.4	8.2	60
	4/17	-	13	9.6	91	1.5	7.7	35
	5/22	-	24	9.1	106	1.6	8.3	80
	6/19	-	21	12.3	137	2.6	8.7	92

Sampling Data (Continued)

Interstate Commission on the Potomac River Basin
1958 - 1959

Station No.	Date	Temp. °C	D.O. ppm	D.O. % Sat.	BOD_5 ppm	pH	Dis. Solids ppm	S. Solids ppm
South Fork Island Ford	7/15/58	26	8.4	102	4.5	8.4	159	2.9
	8/19	24	11.0	129	6.0	8.6	180	5.0
	9/3	22	10.5	119	3.6	8.4	115	2.5
	9/16	22	10.0	113	2.6	8.5	178	3.0
	9/30	18	10.5	110	3.2	8.3	177	3.0
	10/14	16	13.0	131	4.5	8.4	200	2.5
	10/28	13	12.0	113	3.6	8.7	211	7.0
	11/11	10	13.9	121	3.4	8.5	191	1.0
	11/25	10	13.5	119	4.8	8.5	222	3.0
	12/16	3	15.2	116	3.7	8.6	83	1.0
	1/21/59	8	14.3	121	4.0	8.2	186	3.0
	2/3	5	14.3	112	4.6	8.2	165	1.0
	2/17	10	13.2	117	4.5	8.7	159	6.0
	3/3	10	14.2	125	4.6	8.5	179	2.0
	3/24	11	12.3	111	3.6	8.5	147	1.9
	4/14	8	11.0	93	3.3	7.5	60	105
	4/28	16	8.6	86	3.5	7.5	215	12
	5/12	22	9.3	105	2.6	7.9	64	2.5
	5/26	22	8.4	95	3.4	8.0	147	9.0
	6/10	23	8.1	93	4.3	8.2	72	9.0
South Fork Elkton, Va.	7/15/58	26	6.2	75	3.6	8.1	177	6.5
	8/19	24	6.5	76	5.7	8.2	172	22
	9/3	22	7.2	82	3.6	8.4	112	2.5
	9/16	22	6.6	75	3.5	8.1	172	12
	9/30	18	9.9	104	7.4	8.3	154	6.0
	10/14	16	8.7	88	4.2	8.1	211	6.5
	10/28	13	8.7	82	3.2	8.3	235	5.0
	11/11	10	11.5	101	3.0	8.4	180	3.5
	11/25	10	10.0	88	5.5	8.2	221	3.0
	12/16	2	11.6	84	-	8.3	86	1.0
	1/21/59	8	12.2	103	3.8	8.0	187	4.0
	2/3	5	12.2	95	5.3	8.1	152	2.5
	2/17	10	11.1	98	3.6	8.5	234	6.5
	3/3	9	10.6	92	5.0	8.4	150	2.5
	3/24	11	9.7	88	2.8	8.3	122	1.9
	4/14	9	10.7	92	2.9	7.6	82	128
	4/28	16	8.1	81	3.2	7.6	164	13
	5/12	22	7.7	87	2.5	7.8	98	2.0
	5/26	22	7.2	82	2.3	8.1	148	13
	6/10	23	7.3	84	3.5	8.1	106	20

Sampling Data (Continued)

Interstate Commission on the Potomac River Basin
1958 - 1959

Station No.	Date	Temp. °C	D.O. ppm	D.O. % Sat.	BOD_5 ppm	pH	Dis. Solids ppm	S. Solids ppm
South Fork 171-131	7/15/58	26	5.3	65	3.2	7.9	149	5.0
	8/19	24	5.3	62	6.0	7.9	184	67
	9/3	23	6.4	73	2.9	7.9	166	5.5
	9/16	23	7.0	81	3.2	8.1	144	4.5
	9/30	18	7.5	63	3.9	7.9	120	15
	10/14	17	8.7	89	6.0	8.1	184	7.0
	10/28	13	8.7	92	2.9	8.3	191	9.5
	11/11	10	10.2	90	2.0	8.3	183	1.5
	11/25	11	10.7	90	3.9	8.3	186	6.0
	12/6	1	13.1	92	3.6	8.4	95	1.0
	1/21	8	11.0	93	3.9	7.8	185	9.5
	2/3	4	11.1	85	4.4	7.8	178	11
	2/17	9	9.6	83	3.5	8.1	174	12
	3/3	8	9.3	78	4.3	8.1	177	1.5
	3/24	11	9.3	84	2.4	8.0	135	1.6
	4/14	8	10.8	91	3.5	7.6	63	105
	4/28	16	7.5	75	3.2	7.5	91	16
	5/12	22	7.4	84	1.6	7.8	99	2.0
	5/26	21	7.1	79	3.1	7.9	139	19
	6/10	25	7.3	87	3.2	8.0	60	23

Sampling Data (Continued)

Interstate Commission on the Potomac River Basin
1958 - 1959

Station No.	Date	Flow cfs	Temp. °C	D.O. ppm	D.O. % Sat.	BOD_5 ppm	pH	T.Solids ppm	Hardness ppm
South Fork									
171-56	7/58	890	28	5.0	63	1.6	7.9	306	197
	8	997	25	5.0	60	2.0	8.3	190	256
	9	637	23	6.8	78	1.2	8.4	308	236
	10	450	15	7.8	77	1.8	8.6	232	182
	11	530	12	8.8	81	1.4	8.1	267	198
	12	485	2	10.2	74	0.8	8.1	170	184
	1/59	720	0	9.5	65	3.6	7.7	102	117
	2	-	-	-	-	-	-	-	-
	3	1,095	3	8.4	62	3.8	8.6	150	109
	4	1,285	17	-	-	3.2	8.2	171	111
	5	1,335	21	-	-	2.0	8.7	147	84
	6	590	20	-	-	2.0	8.5	224	145
South Fork									
171-54	7/58	-	28	4.8	61	2.8	8.1	266	202
	8	-	25	6.2	74	1.2	8.4	252	291
	9	-	23	1.4	16	6.6	8.4	263	283
	10	-	15	7.8	77	1.8	8.7	270	217
	11	-	13	7.0	52	3.0	8.2	320	215
	12	-	2	9.0	65	3.8	8.4	108	184
	1/59	-	0	8.4	57	4.3	7.7	96	129
	2	-	-	-	-	-	-	-	-
	3	-	3	10.0	74	3.2	8.6	108	103
	4	-	18	-	-	6.2	8.5	136	108
	5	-	21	-	-	1.4	9.1	152	88
	6	-	20	-	-	2.4	7.9	220	148

Sampling Data (Continued)

Interstate Commission on the Potomac River Basin
1958 - 1959

Station No.	Date	Temp. °C	D.O. ppm	D.O. % Sat.	BOD_5 ppm	pH	T.Solids ppm	Hardness ppm
North Fork								
171-N54	7/58	25	5.8	69	1.1	7.9	229	205
	8	23	5.4	62	1.6	8.0	200	365
	9	21	7.4	83	0.4	8.1	234	301
	10	14	8.4	81	1.2	8.4	218	224
	11	12	8.2	76	1.2	8.1	196	265
	12	0	10.0	68	3.2	8.4	348	203
	1/59	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-
	3	4	9.2	70	3.0	8.6	202	131
	4	16	-	-	2.2	8.1	170	125
	5	18	-	-	1.4	8.7	170	91
	6	20	-	-	1.2	7.7	157	156

PART V

APPENDIX V

Sampling Data

Virginia State Water Control Board

1959

Sampling Data

Virginia Water Control Board
1959

Station No.	Date	Temp. °C	D.O. ppm	D.O. % Sat.	BOD_5 ppm	Coliforms /100 ml	pH	Hardness ppm	Turbidity Units
South River S-1	7/59	29	7.6	98	3.4	7,200	7.7	170	40
	8	28	8.8	110	5.0	480	8.8	137	30
	8	27	11.6	144	4.8	3,900	7.7	134	8.0
	9	21	10.0	110	0.8	430	7.6	128	7.6
	9	25	9.2	110	2.0	2,400	8.3	164	35
	10	19	10.0	107	5.2	2,400	6.7	65	7.0
	10	10	9.3	82	2.0	11,000	6.8	768	6.0
	11	6	13.4	107	3.2	-	7.7	123	2.5
	12	5	12.2	95	3.2	-	7.7	103	6.0
South River S-2	7/59	26	8.4	102	2.4	11,000	7.7	164	13
	8	28	12.8	102	5.8	150	7.6	141	3.5
	8	26	6.8	83	0.6	12,000	7.6	147	60
	9	21	6.0	67	3.8	2,400	7.9	155	8.0
	9	23	7.6	88	1.6	15,000	7.4	155	16
	10	19	8.8	94	0.8	24,000	7.2	115	6.0
	10	9	8.8	76	3.6	240,000	7.1	90	7.5
	11	7	11.0	82	2.4	-	6.6	173	4.3
	12	7	11.0	82	2.0	-	7.5	149	1.1
South Fork S-3	7/59	27	11.6	144	1.8	750	8.1	149	7.5
	8	27	10.4	129	-	4,600	8.0	113	1.6
	8	29	10.0	135	3.4	36	7.5	115	13.5
	9	22	13.6	154	1.4	36	8.[illegible]	109	3.0
	9	24	8.8	103	2.4	230	7.3	134	5.0
	10	20	9.2	100	1.4	2,400	6.9	121	14.5
	10	10	9.1	80	2.2	14,000	7.9	71	10
	11	6	12.4	99	3.2	-	7.4	156	3.5
	12	5	13.6	106	3.4	-	8.0	136	3.7
South Fork S-4	7/59	29	8.4	109	12.0	230	8.5	189	28
	8	28	13.6	172	3.6	36	8.6	130	5.0
	8	30	11.2	147	10.4	36	8.1	147	1.8
	9	21	10.4	115	3.2	36	8.7	149	12
	9	27	12.0	149	16.0	-	8.0	86	42
	10	20	8.0	87	7.6	230	7.2	150	7.0
	10	13	8.6	81	11.4	2,400	6.7	123	9.5
	11	6	14.0	112	3.2	-	7.7	154	2.5
	12	6	15.0	120	2.3	-	8.6	141	6.5
Shenandoah R. S-5	7/59	29	12.4	160	6.2	390	8.0	143	36
	8	27	10.0	124	1.4	230	8.0	143	4
	8	28	9.2	116	6.2	-	7.5	139	8.9
	9	21	8.4	94	4.8	430	7.9	160	9.0
	9	27	9.2	114	3.2	-	7.6	147	38
	10	22	8.0	90	2.2	1,500	7.4	117	10.5
	10	12	8.0	74	1.4	11,000	7.1	75	9.5
	11	7	11.2	92	2.0	-	6.8	175	2.0
	12	6	12.6	101	2.0	-	7.5	155	1.5

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PART VI

WATER REQUIREMENTS FOR WATER SUPPLY AND POLLUTION ABATEMENT IN THE SOUTH BRANCH; SMALLER TRIBUTARIES, AND MAIN STEM POTOMAC RIVER ABOVE WASHINGTON, D. C.

PREFACE

This report represents completion of the phase of Potomac River Basin studies dealing with water quality aspects and requirements for water supply and pollution abatement in Upper Potomac River Basin regions.

The information and data contained in this report and prior parts of the entire Potomac River Basin Study Report will be utilized in the preparation of a final report dealing with water supply and low flow augmentation benefits associated with reservoir sites under investigation throughout the Potomac Basin.

The report supplements Parts I and II, "Water Quality Studies" and "Tabulation of Data on Water Uses in the Potomac River Basin," dated November 1958; Part III, "Investigation of Water Uses, Pollution Sources, and Water Quality in the Upper Potomac River Basin," dated December 1959; and complements, in part, evaluations included in the North Branch Potomac River Basin Report, dated February 1961 and the Shenandoah River Basin Report, dated April 1961.

This and all prior studies have been made at the request of the U. S. Army Engineer District, Baltimore Corps of Engineers, as an aid to the development of a comprehensive water resources plan for the Potomac River Basin. Authority for the investigation was granted by the Corps of Engineers in a letter dated June 6, 1958, accepting and approving the plan of study as previously outlined by the Public Health Service in correspondence dated December 3, 1957, and as amended by the Memorandum of Agreement entered into on November 4, 1958, beteeen the Army and the Department of Health, Education, and Welfare, covering assistance to be provided by the Public Health Service to the Corps of Engineers in the implementation of the water supply programs of the Corps of Engineers, authorized under the Water Supply Act of 1958 (Title III, P.L. 500, 85th Congress).

The report deals with six sub-basin study regions and adjoining Main Stem Potomac River areas as shown in Figure 73. These regions are as follows: (1) South Branch Potomac, Little Cacapon, and Cacapon River Basins; (2) Town, Sideling Hill, Tonoloway, and Licking Creek Basins; (3) Conococheague and Antietam Creek Basins; (4) Sleepy, Back, and Opequon Creek Basins; (5) Catoctin Creek (Md.) and Monocacy River Basins; (6) Catoctin Creek (Va.), Goose Creek, and Broad Run Basins.

In dealing with water supply and pollution abatement evaluations in these areas, reference is made throughout the report to data on surface water quality, water uses, and waste sources contained in Report on the Potomac River Basin Study, Part III, "Investigation of Water Uses, Pollution Sources, and Water Quality

in the Upper Potomac River Basin," December 1959. To these basic data are applied projection factors based on the study report prepared for the Corps of Engineers by the U. S. Department of Commerce, Office of Business Economics, Economic Base Survey of the Potomac River Service Area, dated October 31, 1960, and on various projection criteria and rationale as developed by the Public Health Service.

Stream flow requirements for water supply and control of stream water quality are given for the years 1960, 1985, and 2010 for those areas that would be served by the various major reservoirs. Population and employment projections and kinds of employing enterprises in these areas are used as the basis for estimating the water supply and stream quality control requirements. Pollution abatement flow requirements for various stream reaches are those which in combination with optimum conventional waste treatment presently practiced or estimated for the future would result in no lower than the minimum water quality objectives for raw water supply and stream sanitation as established and expected to be adopted by the Interstate Commission on the Potomac River Basin.

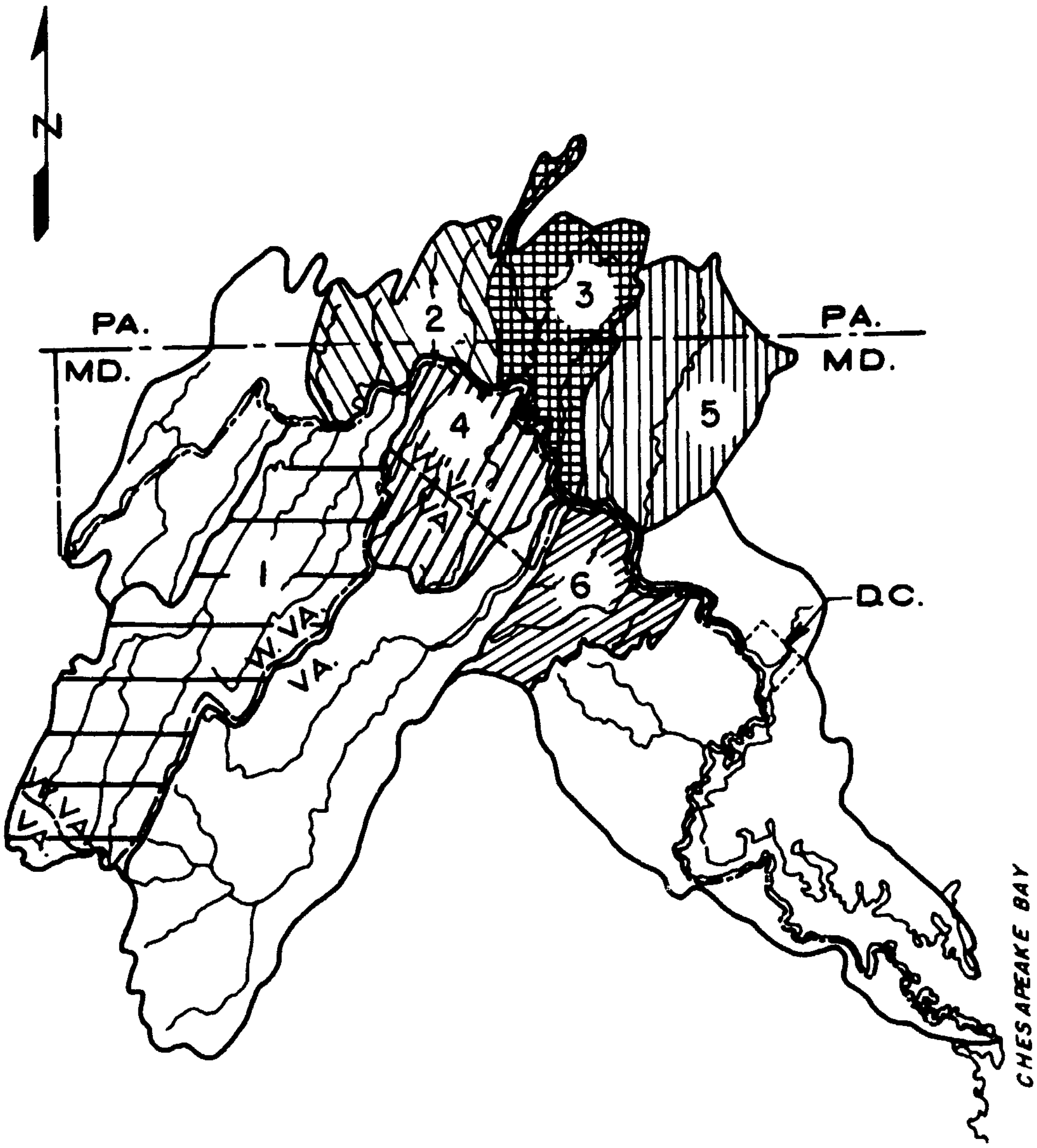
Factors relating to the effects of wastes on water quality and the ability of the streams to assimilate waste effluents are based on various parameters studied during the 1958 Public Health Service field survey and on various other data provided by local, State, and interstate agencies as previously acknowledged in the Potomac River Basin Study Report of December 1959. By incorporating these data in computations involving estimated future conditions, an estimation of stream water quality and corresponding flow requirements to assure maintenance of no less than minimum quality objectives is made possible. (See Table 41).

All stream flow data used in the report were obtained from records documented by the U. S. Geological Survey. Flow data at certain key gaging stations have served as the basis for synthesizing data on available surface water supplies for water use areas not possessing gaging stations and for computing duration-frequency flows in waste receiving reaches where only short periods of record are available.

Table 41

Water Use in the United States
1900-1980 - U. S. Department of Commerce

Use Category	Billion Gallons Per Day - Average		
	1900	1955	1980
Irrigation	20.2	116.3	178.0
Rural	2.0	5.4	7.4
Public	3.0	16.3	32.0
Industrial & Miscellaneous	10.0	49.2	115.0
Steam-Electric	5.0	76.6	161.7
All Uses	40.2	263.8	494.1



POTOMAC DRAINAGE AREA

SUB-BASIN STUDY REGIONS

FIGURE 73

STUDY PROCEDURES

Initial studies began in 1958 when existing information on Potomac River Basin water supplies and waste sources was compiled and presented in the report, Potomac River Basin Study, "Preliminary Compilation of Data on Water Uses in the Potomac River Basin," dated May 1958. Data included in the compilation were obtained from appropriate State and interstate agencies and from existing published data available at that time. Upon review of the initial compilation, various State agencies reported updated revisions which were incorporated in a revised issuance of data presented as Parts I and II, Potomac River Basin Study, November 1958. Because much of the data necessary to the study were still unavailable, Public Health Service personnel conducted visits with various municipalities and industries during the stream sampling program of September and October 1958, to obtain the most recent information possible. These data, together with estimates where information was entirely lacking, constituted another revision in water supply and waste source data and are included in the water quality survey report, Report of the Potomac River Basin Study, Part III, December 1959.

Water quality and quantity data relating to water use areas, waste sources and reservoir sites shown in the Part III, December 1959 report indicate in what areas and to what extent the quality of certain impounded water could be affected by upstream waste sources and in what way the areas adjacent and downstream from various reservoirs might benefit by the use of water from such projects.

Future water needs, waste effects on water quality, and the possible uses that could be made of water storage projects for water supply and pollution abatement in the various areas considered in this report are based on sub-area population and employment figures developed by the Corps of Engineers in consultation with the Office of Business Economics and Public Health Service, as taken from the regional economic evaluation prepared by the Office of Business Economics (OBE). Requirements for municipal and industrial water uses represent estimates made by the Public Health Service on future per capita water demands and industrial water uses as applied to population and employment data projected for specific local areas. Future water quality control aspects reflect waste effects on water quality resulting from specific water uses combined with anticipated waste treatment measures that are expected to be applied or required prior to returning the used water to the stream.

To determine the possible extent to which various reservoirs and associated low flow increases could be utilized for water supply and water quality control requirements for these purposes are established for a 50-year period or to the year 2010. These data are then compared with recorded minimum stream flows from which are determined the quantities and times at which stored water could be utilized.

Requirements for municipal and/or sanitary district water supply are combined by areas (municipal - district) to indicate demands by entire metropolitan populations regardless of the water distribution authority or authorities. Such areas are considered to contain urban, rural residential, and in some cases small town populations plus related commercial, institutional, and small industrial water users.

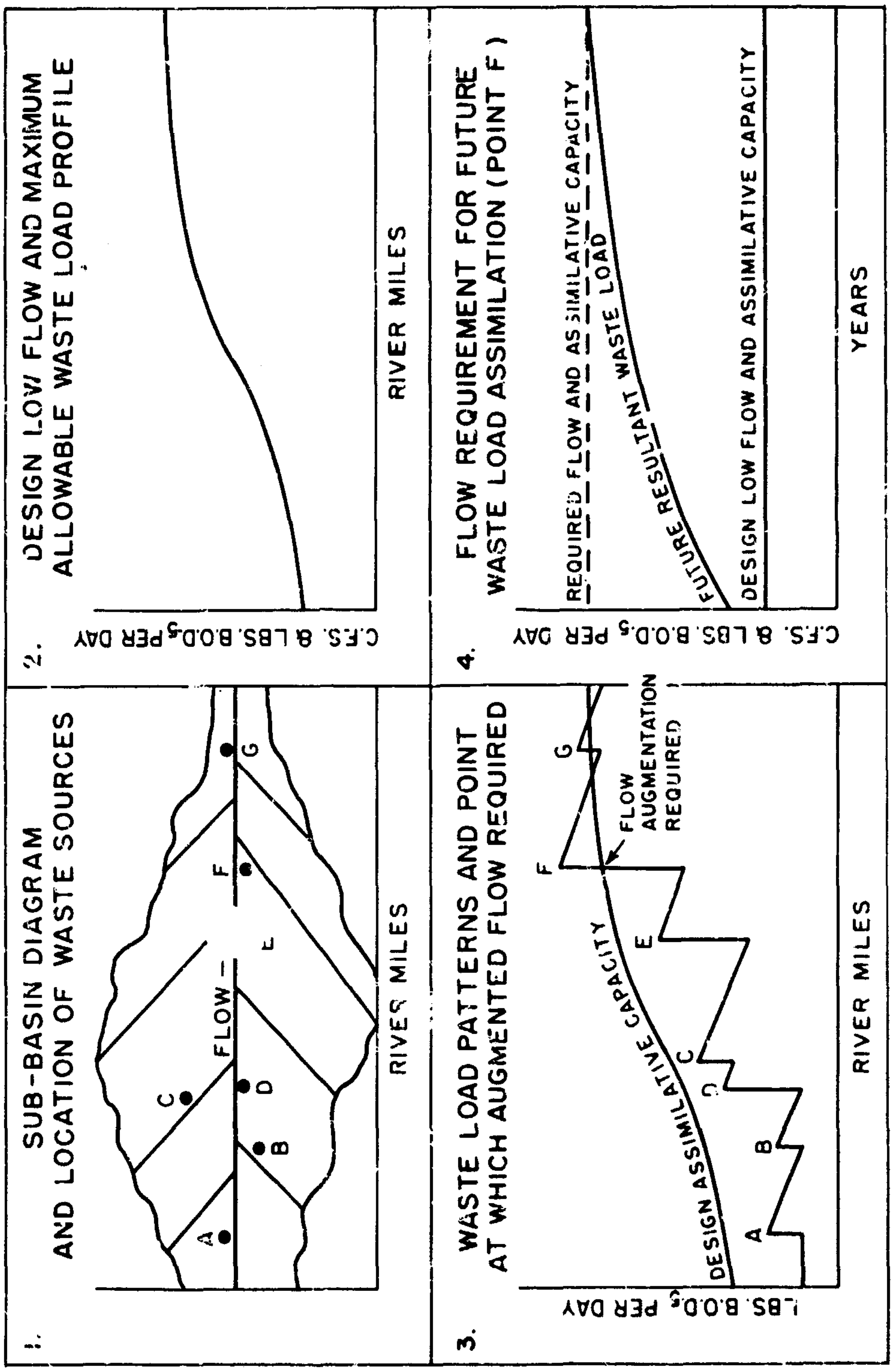
The criteria and rationale that are used to estimate future municipal - district and self-supplied industrial water supply requirements and corresponding waste loads and effects on receiving streams are given in later sections of the report.

The design minimum stream flow data associated with area water supply and pollution abatement requirement evaluations shown in the report were taken from data prepared by the Corps of Engineers in consultation with the Public Health Service. Many of these data represent computations involving flow data regressions and adjustments by drainage areas to various water intake points or waste receiving reaches, based on minimum flows of record at key gaging stations on which sufficient historical data are available. The dependable unregulated stream flows used to determine needs for storage or additional stream flow for water supply throughout the Potomac Basin were obtained from the low flow frequency study made by the Corps of Engineers and are taken to be the minimum flows of record which occurred in 1930, referred to as the 1-day, 30-year stream flow. Main Stem Potomac River flow data take into account regulation of minimum flows from the Savage River Reservoir.

Needs for increased low flow in combination with waste treatment for abatement of pollution in waste receiving reaches are based on minimum average consecutive 7-day recorded flows occurring once in ten years. Though arbitrary, this design minimum level of flow is applied to all points of waste discharge in order to maintain consistency in evaluating augmentation needs in all areas of the Potomac Basin.

CRITERIA FOR DETERMINING PROJECTED WATER REQUIREMENTS FOR WATER SUPPLY AND QUALITY CONTROL IN THE POTOMAC RIVER BASIN

Criteria for determining projected water requirements for water supply and quality control with rationale is the same as developed for the Shenandoah River. This criteria is presented in Part V of the Potomac River Basin Studies, "Investigation of the Shenandoah River Basin," April 1961, on pages 367-373.



GRAPHICAL EXPLANATION OF THE METHOD USED TO DETERMINE FLOW REQUIREMENTS FOR POLLUTION ABATEMENT PURPOSES

FIGURE 74

OBJECTIVES

The objectives of this study are: to identify all water use areas; project future water demands in these areas; relate future waste effects to stream sanitation and re-use of downstream waters; discuss effects of impoundment on water quality; and, to establish types and degrees of waste treatment combined with rates of stream flow required to meet objectives for municipal and industrial raw water quality and general stream sanitation in all major areas of the Potomac River Basin.

It is assumed that the future requirements for water supply given for various areas will be satisfied by use of surface water sources. Although it is known that ground water ecists in many areas, insufficient data is available on the dependability of such sources for future use. Generally, the abundance of ground water appears to exist in areas where more than ample surface water is available to meet demands.

For water use areas located short distances downstream from waste sources, it is recommended that supplies be obtained either directly from major reservoirs or from tributary stream impoundments. In every instance where municipal or domestic wastes are involved it is assumed that waste effluents are, or will be completely disinfected prior to discharge to the stream.

In instances where considered locations for reservoirs are located immediately downstream from waste sources, it is imperative that waste effluents be transported to a point below the dam. Discussions on recreation restrictions, effects of recycling, nutrient effects of recycling, and nutrient effects on algal growth stimulation leading to taste, odor, and filter problems created by waste releases to impoundment waters are given in the Shenandoah River Report, dated April 1961, pages 359 and 360.

The water quality parameters on which flow requirements for pollution abatement are based were described previously in the section on pollution abatement criteria. It is therefore assumed that municipal waste treatment facilities will include screening, primary sedimentation, oxidation, final sedimentation, effluent chlorination, and sludge digestion, and that over the 50-year period under study, up to 85 per cent BOD reductions will at all times be maintained. The flow requirements given for the years 1960, 1985, and 2010 assume 75, 80, and 85 per cent BOD removals, respectively, by conventional treatment practices prior to discharge. By this, it is assumed that plant capacities will be enlarged at various intervals of time to compensate for waste volume increases; presumably, replacements of units will be made as warranted.

Since it was found throughout the Potomac Basin that industrial waste treatment efficiencies differed greatly depending upon types of waste, it is assumed that future efficiencies will be similar and in

some cases greater than presently practiced. For those industries having no treatment, an estimated treatment efficiency is assumed with the expectation that facilities will be installed at a later date.

Stream quality objectives to be achieved by waste treatment and low flow augmentation are those established by the Interstate Commission on the Potomac River Basin for Class "C" water quality, as shown in Table 42. It is assumed that coliform bacteria (MPN) in the stream will be controlled by waste disinfection to monthly averages of no greater than 500 to 5,000 organisms per 100 milliliters and that toxic substances--oil, tar, free acid, floating and settleable solids, and taste and odor producing substances--will either be removed by waste treatment or be prevented from entering the streams by other means.

Stream sampling results show all stream waters considered in this study to be within the pH range of 6.0 to 8.5. Assuming that free acids are not allowed to enter the stream, it may be considered that the natural pH of stream water will continue to be within the acceptable pH range for water supply and protection of aquatic life.

Assuming that all of the foregoing waste treatment and waste disposal measures are applied, there is still the problem of assuring sufficient stream flow in waste receiving reaches for achievement of dissolved oxygen objectives set forth in the Interstate Commission objectives for dissolved oxygen and biochemical oxygen demand.

The pollutional significance of these parameters and associated temperature effects are given on pages 18, 19, and 20 of the Shenandoah River Basin Report.

Due to wide differences in stream and waste characteristics found throughout the Potomac Basin, considerable variations in concentrations of BOD associated with D.O. levels occur. In many instances, depending upon location of certain waste sources in relation to others, the 5-day BOD (BOD_5) concentrations associated with D.O. levels of 5 parts per million may vary from one reach to another or from one stream to another by as much as 5 ppm (range of 3 to 8 ppm BOD_5). Therefore, pollution abatement flow requirements for assimilation of oxygen demanding wastes to meet Interstate Commission objectives for dissolved oxygen necessarily disregard the objectives for BOD_5.

To complete the satisfaction of Class "C" water quality objectives, low flow augmentation where needed is based on the rate of flow required to maintain minimum dissolved oxygen levels at 5 ppm with average monthly minimum levels at 6.5 ppm. It should be understood that the magnitude of stream flow required to maintain these objectives will often accomplish reductions in concentrations of color, taste, odors, and various types of persistent waste chemicals not possible to reduce by any other known treatment means.

TABLE 42

Interstate Commission on the Potomac River Basin

Minimum Water Quality Criteria for Streams in the Potomac River Basin

Approved 8 August 1946

	CLASS A Drinking Water (No treatment except cl.)	CLASS B Bathing, Fish Life	CLASS C Domestic Water Supplies (Before complete treatment) Industrial Process Water	CLASS D General Sanitary Condition - to prevent nuisance
Coliform Bacteria	0 - 50	Mo. av. 50 - 500 Max. not over 1,000	Mo. av. 500 - 5,000	----------
Color, ppm	0 - 10	20 (desirable)	Amt. of color and turbidity allowed which can be removed by standard equipment and practices	----------
Turbidity, ppm	0 - 10	40 (desirable)	----------	----------
pH	6.0 - 8.0	6.0 - 8.5	6.0 - 8.5	6.0 - 8.5
5-Day BOD, ppm	----------			
Monthly av., ppm	----------	1.5	2.0	3.0
Max. observation, ppm	----------	3.0	4.0	5.0
Dissolved Oxygen, ppm				4.0
Monthly av., ppm	7.5	6.5	6.5	Min. daily ave. 3.0
Min. observation, ppm	6.5	5.0	5.0	Absolute min. 2.0
Other Conditions	No toxic substances, oil, tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste - or odor-producing substances.	Same as A	Same as A	No toxic substances, oils, tars, or free acid at any time. No floating solids or debris except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

NOTE: These criteria are to be used only in conjunction with a sanitary survey as a guide in determining the minimum water quality for the various classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.

DESCRIPTION OF AREA AND STUDY RESULTS

GENERAL

The six sub-study regions dealt with in subsequent chapters comprise 42 per cent (drainage area - 6,179 square miles) of the total land area of the Potomac River Basin and 56 per cent of the drainage area lying above Washington, D. C. Parts of West Virginia, Maryland, Pennsylvania, and Virginia lie in this area.

At the present time, approximately 452,400 persons reside within the region. Of this number, 79,000 reside on farms, 163,200 reside in rural residential areas, 25,500 reside in small towns, and 184,700 reside in urban communities. By the year 2010, it is expected that farm populations will have decreased to 54,300, rural residential populations increased to 356,800, small town populations to 54,000, and urban populations to 538,400, resulting in a total population of 1,003,500.

Both surface and ground water are used for water supply throughout this region. Generally, surface sources are used to supply all relatively large uses. Many surface supplies are obtained from small watershed impoundments, rather than from the natural stream flow, for such reasons as: undependability of natural stream flows, flooding possibilities, and unsuitability of water quality for supply purposes. Surface supplies that are taken from the natural stream flow are often operated in conjunction with standby wells or springs to supplement the supply during low flow periods.

Water is used in this study region for municipal purposes, industrial processing and cooling, irrigation, recreation, and disposal of wastes. Surface supplies serve the needs of about 24 major municipalities and 32 self-supplied industrial users. Whereas approximately 196,000 persons are now served with water from municipal systems in this region, it is anticipated that by the year 2010, about 663,000 persons will be served from both municipal systems and sanitary district systems. At the present time, total water use by these major municipalities is 22 MGD. By the year 2010, it is estimated that 128 MGD will be required. Self-supplied industrial water requirements for processing are expected to increase from the present 8 MGD to about 27 MGD by the year 2010, and cooling requirements from 559 MGD to 1,335 MGD within this period of time.

Municipal and/or industrial wastes are received in many of the streams in this study region of the Potomac River Basin. In most instances, some form of waste treatment is applied to wastes before discharge to the receiving stream. Depending upon the amount of flow in the receiving stream, the degree of waste treatment may or may not be sufficient to prevent stream quality degradation, resulting in interference with water uses or propagation of aquatic life downstream.

It has been determined that with ultimate optimum conventional waste treatment as known today, approximately 12 stream reaches in this region will be adversely affected by the disposal of wastes during return periods of recorded low flow. Characteristically, the development activities in the Potomac Basin are centered in upper watershed areas where shortages of water and waste receiving flow become extremely critical.

Various aspects concerned with details on water supply and water quality control requirements in each of the sub-study regions are given in sections to follow. All data presented are based on the criteria and objectives previously described. Where major reservoir sites are appropriately located with respect to water supplies and critical stream reaches, a description is given of the site and of conditions relating to impounded water quality, possible use restrictions, and a suggested method of water releases.

SOUTH BRANCH, LITTLE CACAPON AND CACAPON RIVER BASINS

DESCRIPTION OF AREA AND MAJOR RESERVOIRS

The South Branch Potomac, Little Cacapon, and Cacapon River Basins comprise a portion of the Appalachian area located in Virginia and West Virginia. The South Branch Potomac Basin is the second largest sub-basin of the Potomac with a drainage area of 1,493 square miles, exceeded in size only by the Shenandoah River Basin (3,054 square miles). The Cacapon River Basin, paralleling and lying east of the South Branch, is the fifth largest sub-basin of the Potomac with a drainage area of 683 square miles, being exceeded in size by the Shenandoah, South Branch Potomac, North Branch Potomac, and Monocacy River Basins.

Included within the South Branch Basin are: a small portion of Highland County, Virginia; part of Grant County, West Virginia; all of Pendleton County, West Virginia; and portions of Hardy and Hampshire Counties of West Virginia. The remaining portions of Hardy and Hampshire Counties are located in the Little Cacapon and Cacapon River Basins, with a portion of Morgan County, West Virginia, located in the lower Cacapon Basin area.

The South Branch converges with the North Branch to form the headwaters of the Potomac River near Old Town, Maryland, 285 river miles from the mouth of the Potomac at Chesapeake Bay and 175 river miles above Washington, D. C. The Little Cacapon and Cacapon Rivers enter the Potomac River downstream from the confluence of the North and South Branches of the Potomac River at river mileages above Washington, D.C., of 170 and 138 miles, respectively.

From the upper to lower elevations, these basins are oriented lengthwise in a northeasterly position. The South Branch Basin extends

southwesterly from the Potomac River about 130 miles, and the Little Cacapon and Cacapon Basins extend southwesterly from the Potomac River about 15 and 80 miles, respectively (see Figure 75).

The South Branch, which flows a 133 mile course through rugged, narrow valleys to wide valley farm land in the lower reaches, rises near Monterey in Highland County, Virginia. The Little Cacapon River rises near Augusta, West Virginia, and the Cacapon River's source is in the southeast corner of Hardy County about 5 miles west of Mathias, West Virginia. The Cacapon River flows across portions of Hardy and Hampshire Counties and across the west central portion of Morgan County to the Potomac. The upper two-thirds of the Cacapon River is fairly straight with steep rapids and small waterfalls. The lower third meanders through a wide valley.

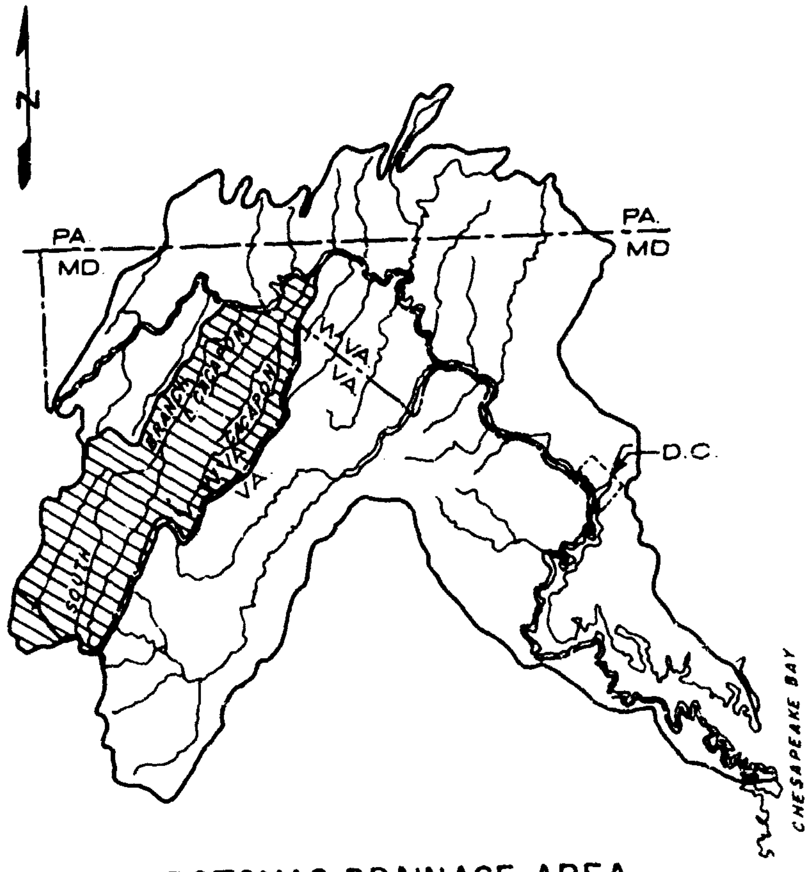
The watershed areas in this region are composed of mountainous and steep valley terrain, giving rise to rapid runoff and periods of low sustained stream flow.

For 34 years (1899-1901, 1903-1905, 1928-1958) of stream gaging near Springfield, West Virginia (drainage area - 1,471 square miles), the average flow of the South Branch has been 1,262 cubic feet per second (cfs) with extremes of 143,000 cfs and 56 cfs. For 35 years (1923-1958) of stream gaging near Great Cacapon, West Virginia (drainage area - 677 square miles), the average flow of the Cacapon River has been 566 cfs with extremes of 87,600 cfs and 34 cfs. No gaging records are available for Little Cacapon River.

There are four reservoir sites under consideration for the South Branch and Cacapon regions. Two of the sites considered are in the South Branch Basin--one in the Little Cacapon Basin and one in the Cacapon River Basin (see Figure 76). The reservoir sites in the South Branch Basin include one immediately below the confluence of the North Fork and main stem of the South Branch, and one site immediately upstream from the mouth of the South Branch.

The uppermost reservoir site in the South Branch Basin is on the South Branch upstream from Petersburg, West Virginia. The drainage area is 640 square miles and the valley at the site is 700 feet wide. The elevation of the conservation pool would be 1,160 feet and the maximum water surface elevation 1,190 feet. The reservoir would extend 5.7 miles up the North Fork and 10.5 miles up the South Branch, covering a total of 2,900 acres.

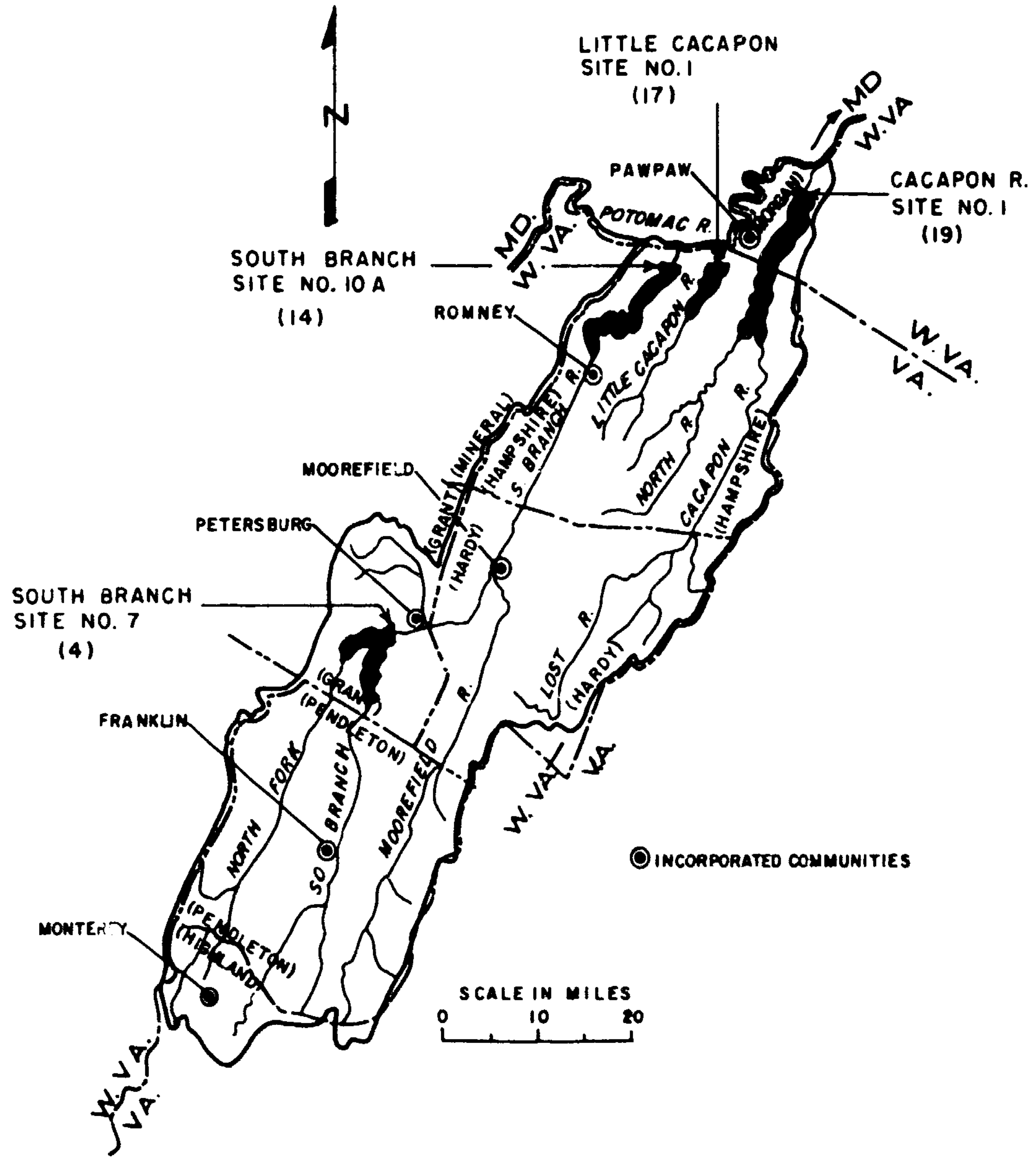
The lower South Branch Basin reservoir site is located about 28 miles downstream from Romney, West Virginia, at the second horseshoe bend of the South Branch above the mouth of the river. The drainage area is 1,486 square miles and the valley width at the site is 3,550 feet. The elevation of the conservation pool would be 689 feet and the maximum water surface elevation 709 feet. The reservoir would be 31 miles long and would cover 10,300 acres. There are several small communities and fishing cottages in this reservoir area.



POTOMAC DRAINAGE AREA

SUB-BASIN STUDY REGIONS
SOUTH BRANCH, LITTLE CACAPON AND CACAPON RIVERS

FIGURE 75



POTOMAC SUB-TRIBUTARIES

SOUTH BRANCH, LITTLE CACAPON AND CACAPON RIVERS PROPOSED RESERVOIR SITES

FIGURE 76

The reservoir site in the Little Cacapon River Basin is located 3.4 miles upstream from the mouth of the Little Cacapon River. The drainage area is 101 square miles and the valley width at the site is 1,370 feet. The elevation of the conservation pool would be 690 feet and the maximum water surface elevation would be 713 feet. The reservoir would be 6 miles long, covering 1,030 acres. No significant development exists in the reservoir area.

The reservoir site in the Cacapon Basin is at Edes Fort, West Virginia, 5 miles upstream from the south of the Cacapon River. The drainage area is 679 square miles and width of the valley at the site is 900 feet. The elevation of the conservation pool would be 675 feet and the maximum water surface elevation 698 feet. The reservoir would be 29.5 miles long, covering an area of 5,580 acres, The community of Forks of Cacapon and many summer cottages lie within the reservoir area.

PRESENTATION OF DATA

POPULATIONS - PRESENT AND FUTURE

At the present time, approximately 37,000 persons reside in the South Branch, Little Cacapon, and Cacapon River Basin area, constituting about one-twentieth of the Upper Potomac Basin populations. About 6,600 persons or 8 per cent of all persons residing in these basin areas are located in urban or incorporated communities (see Figures 77 and 78). About 15 per cent of the urban population in the three basins reside in the South Branch area.

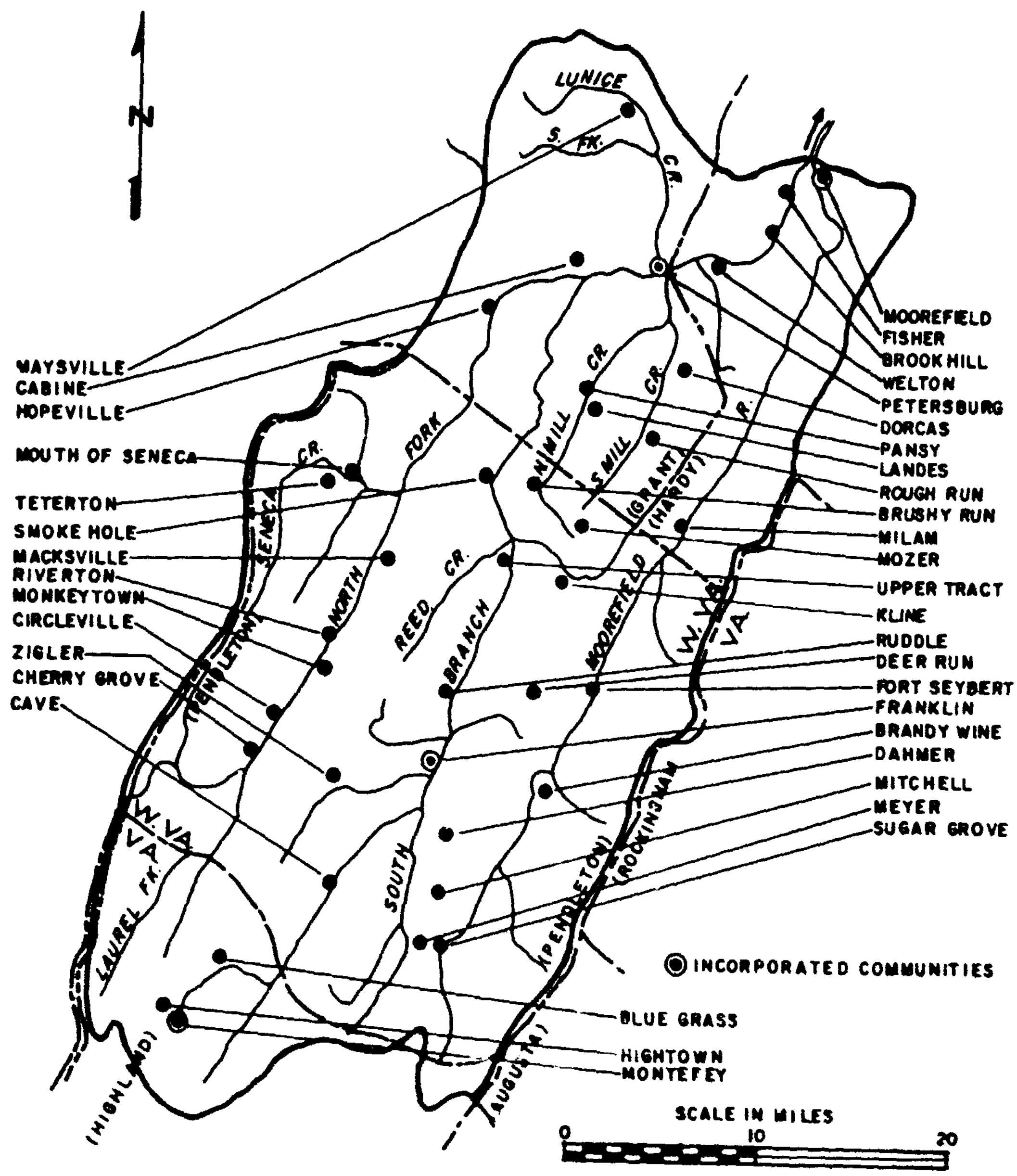
It is estimated that by the years 1985 and 2010, the populations of these three basins will be 52,900 and 70,700, respectively (see Table 43). Urban populations by the years 1985 and 2010 will have increased to 13,400 and 22,800, respectively.

The locations of major population centers for which projected water supply and waste source information is desired are shown in Figure 79. Table 44 shows the percentage breakdown of urban country populations expected to form the nucleus of these development centers.

WATER SUPPLY REQUIREMENTS

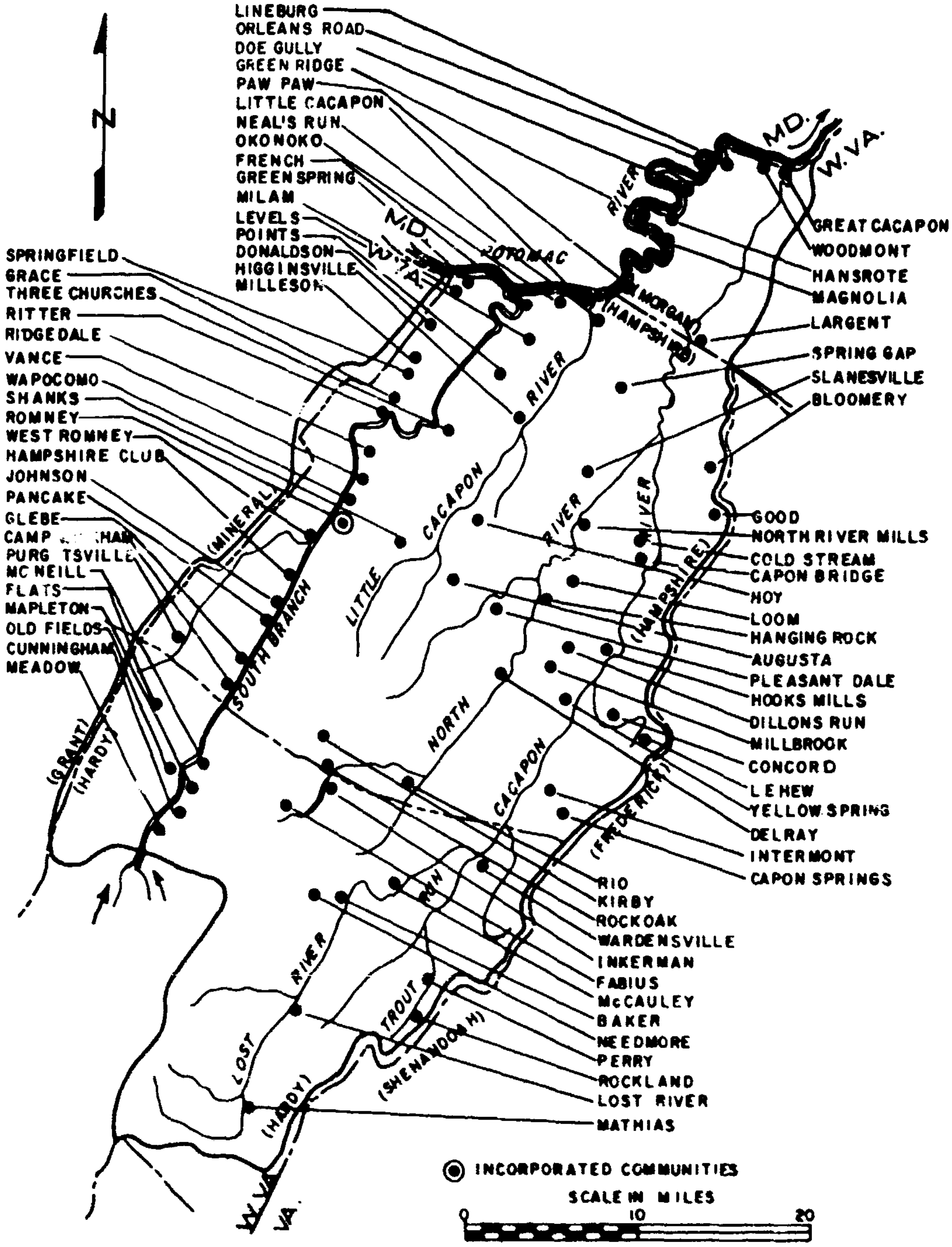
Urban populations and associated rural residential populations projected for water use centers located within proximity of downstream from major reservoirs are shown in Table 45. The projected average and maximum daily municipal - district water supply requirements are given in Table 47, and were obtained by applying per capita daily rates shown in Table 46 to area populations presented in Table 45.

The self-supplied industrial processing requirement shown for Subdivision 4, Table 47, represents an annual increase of 4 per cent of 1960 uses, based on Office of Business Economic's employment



POTOMAC SUB-BASIN AREA
UPPER SOUTH BRANCH BASIN
STATES, COUNTIES AND COMMUNITIES

FIGURE 77



POTOMAC SUB - BASIN AREA

LOWER SOUTH BRANCH, LITTLE CACAPON AND CACAPON BASINS STATES, COUNTIES AND COMMUNITIES

FIGURE 78

Table 43

South Branch, Little Cacapon, and Cacapon River Basins

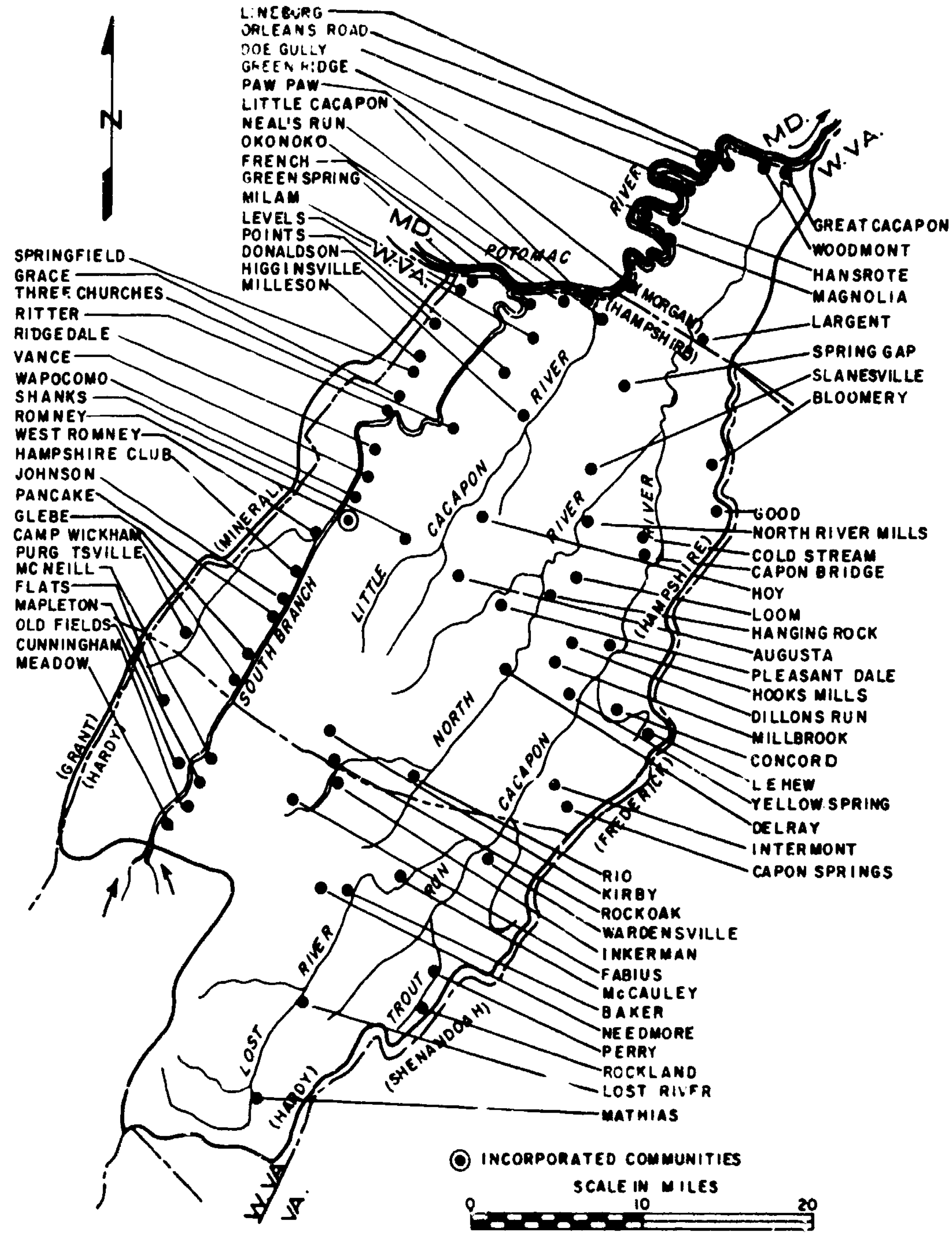
Populations by Counties and Residence Categories
1960 - 2010

W. Va. County Name	% in Basin	Total	Farm	Non-Farm Residential	Non-Farm Small Town	Non-Farm Urban
1960						
Pendleton	100	8,100	4,600	2,300	200	1,000
Grant	50	4,100	1,650	1,050	300	1,100
Hardy	100	9,300	4,400	2,800	200	1,900
Hampshire	100	11,700	4,500	4,400	800	2,000
Morgan	45	3,780	1,170	1,620	405	585
Totals		39,980	16,320	12,170	1,905	6,585
1985						
Pendleton	100	11,700	4,300	4,600	300	2,500
Grant	50	6,350	1,550	2,100	500	2,200
Hardy	100	17,100	4,400	7,000	2,400	3,300
Hampshire	100	13,500	4,100	4,400	400	4,600
Morgan	45	4,230	990	2,025	405	810
Totals		52,880	15,340	20,125	4,005	13,410
2010						
Pendleton	100	14,900	3,700	6,700	400	4,100
Grant	50	9,050	1,300	3,500	550	3,700
Hardy	100	18,400	3,500	5,300	700	8,900
Hampshire	100	23,600	3,700	10,500	4,500	4,900
Morgan	45	4,725	765	2,385	405	1,170
Totals		70,675	12,965	28,385	6,555	22,770

Table 44

South Branch, Little Cacapon, and Cacapon Basins
Population Subdivisions

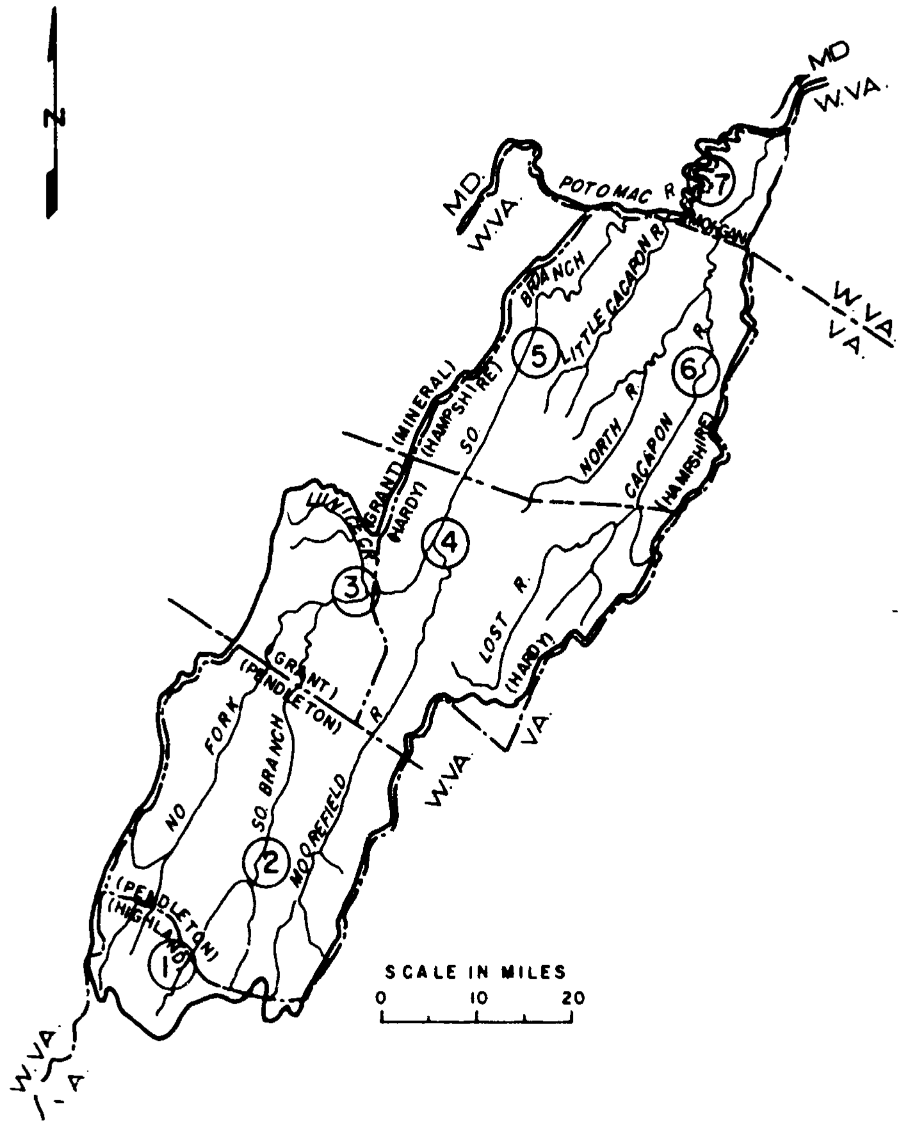
Subdivision Number	Location of Subdivision: Sub-Basin	Location of Subdivision: County	% County Population
Sub. No. 1	Upper South Br.	Pendleton, W. Va.	20
Sub. No. 2	Upper South Br.	Pendleton, W. Va.	80
Sub. No. 3	Middle South Br.	Grant, W. Va.	50
Sub. No. 4	Middle South Br.	Hardy, W. Va.	100
Sub. No. 5	Lower South Br.	Hampshire, W. Va.	75
Sub. No. 6	Lower South Br.	Hampshire, W. Va.	25
Sub. No. 7	Potomac River	Morgan, W. Va.	45



POTOMAC SUB - BASIN AREA

LOWER SOUTH BRANCH, LITTLE CACAPON AND CACAPON BASINS STATES, COUNTIES AND COMMUNITIES

FIGURE 78



POTOMAC SUB-BASIN AREA

SOUTH BRANCH, LITTLE CACAPON AND CACAPON RIVERS DEVELOPMENT CENTERS

FIGURE 79

Table 45

South Branch, Little Cacapon, and Cacapon Basins

Populations Served by Central Water Supply Systems in Vicinity and Downstream of Major Reservoirs

Sub-Basin and Identifying Community	Subdivision Number	Subdivision Populations 1960	1985	2010
Middle South Branch Petersburg, W. Va.	3			
Rural Residential		265	1,050	2,625
Urban		1,735	2,200	3,700
Total		2,000	3,250	6,325
Middle South Branch Moorefield, W. Va.	4			
Rural Residential		700	2,200	3,970
Urban		1,900	4,600	8,900
Total		2,600	6,800	12,870
Lower South Branch Romney, W. Va.	5			
Rural Residential		825	2,625	5,905
Urban		1,675	2,475	3,675
Total		2,500	5,100	9,580
Lower Cacapon River Capon Bridge, W. Va.	6			
Rural Residential		275	875	1,970
Urban		500	825	1,225
Total		775	1,700	3,195
Potomac River Paw Paw, W. Va.	7			
Rural Residential		405	1,015	1,790
Urban		585	810	1,170
Total		990	1,825	2,960

Note: Subdivision Nos. 1 and 2 not within reasonable proximity of major reservoir. Subdivision No. 6 served by ground water.

Table 46

South Branch, Little Cacapon, and Cacapon Basins

Per Capita Daily Municipal - District Demand Rates

Sub-Basin and Identifying Community	Subdivision Number	Per Capita Daily Gal. 1960	1985	2010
Middle South Branch Petersburg, W. Va.	3			
Average		100	138	175
Maximum		150	188	225
Middle South Branch Moorefield, W. Va.	4			
Average		103	142	180
Maximum		154	193	231
Lower South Branch Romney, W. Va.	5			
Average		66	91	116
Maximum		99	124	149
Lower Cacapon River Capon Bridge, W. Va.	6			
Average		54	74	95
Maximum		81	101	122
Potomac River Paw Paw, W. Va.	7			
Average		55	76	96
Maximum		83	104	124

Table 47

South Branch, Little Cacapon, and Cacapon Basins

Municipal - District and Industrial Water Requirements
Relative to Dependable Surface Water Supply

Sub-Basin and Identifying Community	Subdivision Number	Million Gallons Per Day 1960	1985	2010
Middle South Branch Petersburg, W. Va.	3			
Municipal - District-Average		0.20	0.45	1.11
Municipal - District-Maximum		0.30	0.61	1.43
Surface Supply		30.4	30.4	30.4
Middle South Branch Moorefield, W. Va.	4			
Municipal - District-Average		0.27	0.97	2.32
Municipal - District-Maximum		0.40	1.31	2.77
Industrial Processing		0.30	0.60	.90
Totals-Average		0.57	1.57	3.22
Totals-Maximum		0.70	1.91	3.67
Surface Supply		4.5	4.5	4.5
Lower South Branch Romney, W. Va.	5			
Municipal - District-Average		0.16	0.47	1.11
Municipal - District-Maximum		0.24	0.63	1.43
Surface Supply		39.4	39.4	39.4
Potomac River Paw Paw, W. Va.	7			
Municipal - District-Average		0.06	0.14	0.29
Municipal - District-Maximum		0.09	0.19	0.37
Surface Supply		170	170	170

Note: Subdivision No. 6 served by ground water.

projections for chemical and food processing industries in the region. It can also be seen by an inspection of supply requirements relative to the dependable stream flows shown in Table 47 where water storage benefits may or may not accrue.

QUALITY CONTROL REQUIREMENTS

In Table 48 are shown the projected waste loads and design loads for the stream and waste receiving flows required to maintain the quality objective in stream reaches downstream from the major reservoirs. The waste loads or population equivalents (P.E.) of 5-day 20°C biochemical oxygen demand (BOD_5) shown in Table 48 constitute an estimate of residual materials contained in projected municipal and/or industrial treatment plant effluents received in local and upstream reaches. Design P.E. for the particular stream reaches represent associated stream assimilative capacities originating from computations involving deoxygenation and reaeration velocity constants obtained from stream sampling in these areas. Points at which samples were collected are shown in Figure 80, the data for which are appended to the December 1959 Potomac River Basin Study Report as Stations C-1, B-5, and C-2.

The requirements for quality control and design minimum 7-day, 10-year return flows shown in Table 48 may be compared for purposes of determining locations and amounts of increased stream flow required to meet objectives.

MAJOR RESERVOIRS - WATER SUPPLY AND QUALITY CONTROL

Discussions on water quality and sanitation relative to possible reservoir sites in the Potomac Basin are given on pages 61-71 of the December 1959 Potomac River Basin Study Report. Discussions on the four reservoir sites now under consideration in this study region are given on pages 66-69 of the December 1959 report as follows:

	Number (Present)
1. South Branch above Petersburg, West Virginia, Site No. 7	4
2. South Branch near Springfield, West Virginia, Site No. 10A	14
3. Little Cacapon River, West Virginia, Site No. 1	17
4. Cacapon River, West Virginia, Site No. 1	19

To determine whether or not stored water could be utilized and therefore be assigned a benefit for water supply and pollution abatement purposes, the requirements, where waters are removed and returned as waste, are added together and compared with recorded minimum or statistical design minimum flows. Table 49 shows the total requirements with design minimum flows included as a means of determining needs for the utilization of stored water.

A supplemental report devoted to benefit analyses will include detailed studies on storage benefits in this and all downstream study areas.

TOWN, SIDELING HILL, TONOLOWAY, AND LICKING CREEK BASINS

DESCRIPTION OF AREA AND MAJOR RESERVOIRS

These relatively minor sub-basins of the Potomac Basin comprise a portion of the Appalachian area located in Maryland and Pennsylvania. The total watershed area included in these sub-basins is 588 square miles of which 119 square miles are located in Allegany and Washington Counties of Maryland and 469 square miles in Bedford, Fulton, and Franklin Counties of Pennsylvania.

Town Creek, Sideling Hill Creek, Tonoloway Creek, and Licking Creek enter the Potomac River from the north at river mileages above Washington, D. C., of 172, 141, 127, and 121 miles, respectively.

From the upper to lower elevations, these basins are oriented lengthwise in a southerly position. Town Creek Basin (156 square miles) extends northerly from the Potomac River about 25 miles; Sideling Hill Creek Basin (140 square miles) extends about 16 miles; Tonoloway Creek Basin (114 square miles) extends about 25 miles; and Licking Creek Basin (214 square miles) extends a distance of 30 miles. All of these creeks have their sources in Pennsylvania (see Figure 81). The watershed areas are characterized by relatively high mountain ranges and steep valleys which promote rapid runoff. No stream gaging records are available for these streams.

There is one reservoir under consideration for each of these four watersheds (see Figure 82). The Town Creek site is located at the easternmost curve in the creek, approximately 9 miles above the mouth. The drainage area is 145 square miles, and the valley width at the site is 1,260 feet. The elevation of the conservation pool would be 713 feet with maximum water surface elevation at 734 feet. The reservoir would be 9.7 miles long, covering 1,530 acres. There is no significant development in the reservoir area.

The Sideling Hill Creek site is located 1.7 miles above the mouth of the creek. The drainage area is 104 square miles, and the valley at the site is 1,250 feet wide. The elevation of the conservation

Table 48

South Branch, Little Cacapon, and Cacapon Basins

Flow Requirements for Pollution Abatement
by Subdivision Stream Reaches

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
South Branch Petersburg Reach	3			
P.E. Received		500	650	950
Design P.E. per cfs		240	240	240
cfs Required		2.1	2.7	4
7-day, 10-year cfs		56	56	56
South Branch, South Fork Moorefield Reach	4			
P.E. Received-Municipal		625	1,360	1,930
P.E. Received-Industrial		3,360	4,695	6,020
Total P.E. Received		3,985	6,055	7,950
Design P.E. per cfs		240	240	240
cfs Required		16.6	25.3	33
7-day, 10-year cfs		10	10	10
South Branch Confluence with South Fork	4a			
Upstream Residual		4,360	6,430	8,663
Design P.E. per cfs		196	167	140
cfs Required		22.3	38.5	62
7-day, 10-year cfs		64	64	64
South Branch Romney Reach	5			
P.E. Received		500	1,020	1,440
Upstream Residual		2,440	3,600	4,850
Total Received		2,940	4,620	6,290
Design P.E. per cfs		130	130	130
cfs Required		22.6	35.5	48.5
7-day, 10-year cfs		76	76	76
Cacapon River Capon Bridge Reach	6			
P.E. Received		190	340	480
Design P.E. per cfs		220	220	220
cfs Required		0.9	1.5	2.2
7-day, 10-year cfs		22	22	22

Table 48 (continued)

South Branch, Little Cacapon, and Cacapon Basins

Flow Requirements for Pollution Abatement
by Subdivision and Stream Reaches

Stream Name and Waste Receiving Reach		Subdivision Number	1960	1985	2010
Potomac River					
Paw Paw Reach		7			
P.E. Received			250	365	440
Upstream Residual,	South Branch		590	920	1,260
	North Branch		12,140	21,920	31,700
Total Received			12,980	23,204	33,400
Design P.E. per cfs			220	210	196
cfs Required			59	110	170
7-day, 10-year cfs			275	275	275

Table 49

South Branch, Little Cacapon, and Cacapon Basins

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
South Branch								
Petersburg, W. Va.		2.1		2.7		4.0	47	56
Municipal								
Average	0.3		0.7		1.7			
Maximum	0.5		1.0		2.2			
Total								
Average		2.4		3.4		5.7		
Maximum		2.6		3.7		6.2		

Remarks - no storage benefits.

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
South Branch-South Fork								
Moorefield, W. Va.		16.6		25.3		33	7	10
Municipal								
Average	0.4		1.5		3.6			
Maximum	0.6		2.0		4.3			
Industrial	0.5		1.0		1.4			
Total								
Average		17.5		27.8		38		
Maximum		17.7		28.3		38.7		
Increase Required		7.7		18.3		28.7		

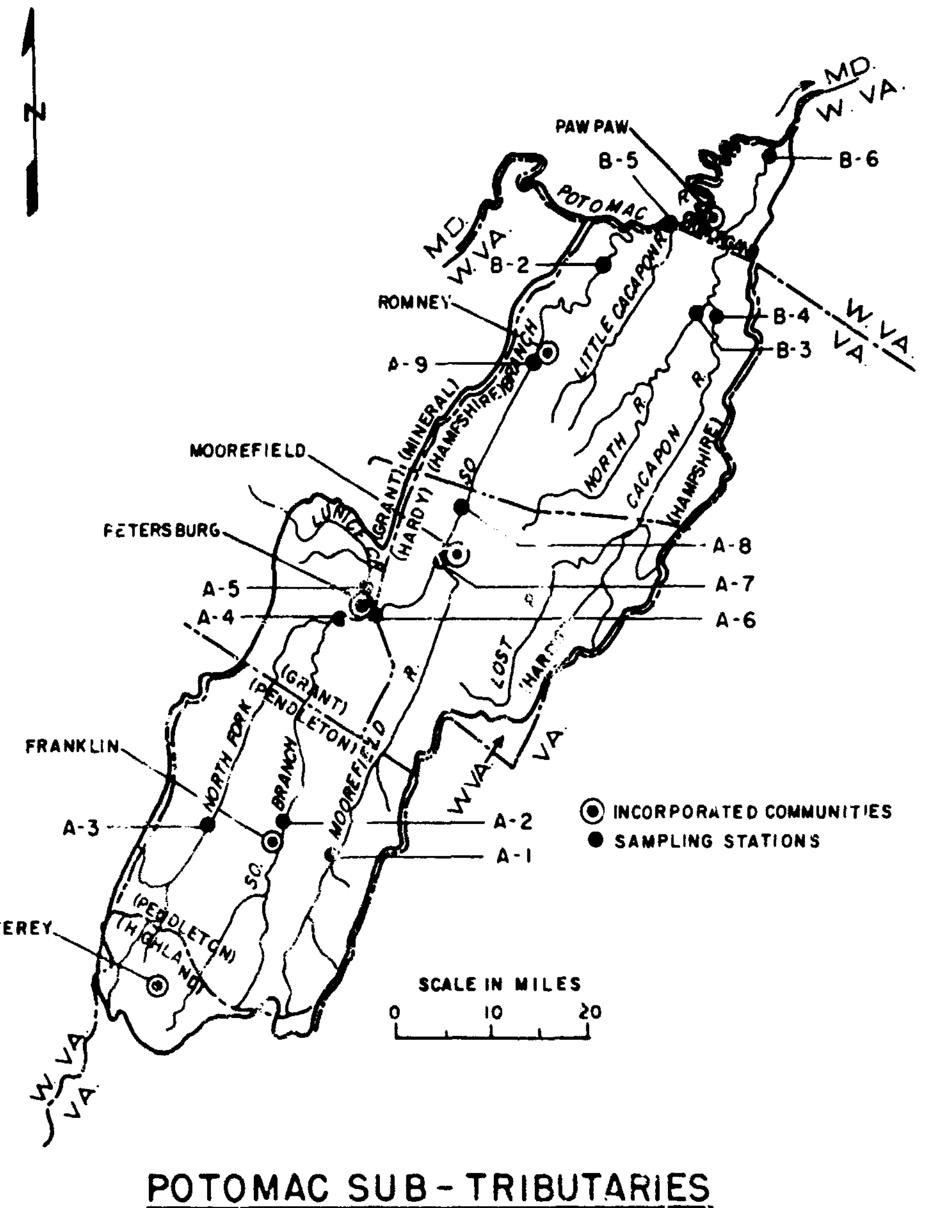
Remarks - storage benefits.

Table 49 (continued)

South Branch, Little Cacapon, and Cacapon Basins

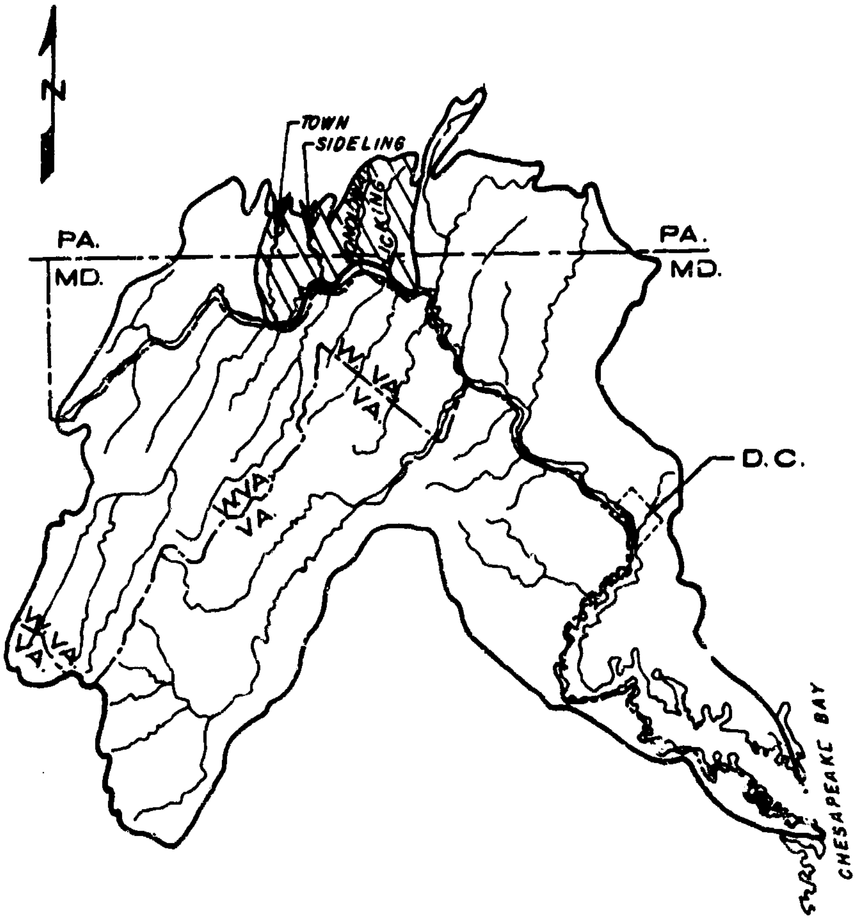
Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
South Branch								
Below mouth of Moorefield River		22.3		38.5		62	51	64
Remarks - no storage benefits.								
South Branch								
Romney, W. Va.		22.6		35.0		48.5	61	76
Municipal								
Average	0.3		0.7		1.7			
Maximum	0.5		1.0		2.2			
Total								
Average		22.9		35.7		50.2		
Maximum		23.1		36.0		50.7		
Remarks - no storage benefits; upstream losses considered not to significantly affect minimums.								
Cacapon River								
Capon Bridge, W. Va.	Ground	0.9	Ground	1.5	Ground	2.2	18	22
Remark - no storage benefits.								
Potomac River								
Paw Paw, W. Va.		59		110		170	261	275
Municipal								
Average	0.1		0.2		0.5			
Maximum	0.2		0.3		0.6			
Total								
Average		59.1		110.2		170.5		
Maximum		59.2		110.3		170.6		
Remark - no storage benefits; use of Site 14 would reduce quality control requirement.								



POTOMAC SUB-TRIBUTARIES
SOUTH BRANCH, LITTLE CACAPON AND CACAPON RIVERS
SAMPLING STATION LOCATIONS-PHS SURVEY 1958

FIGURE 80

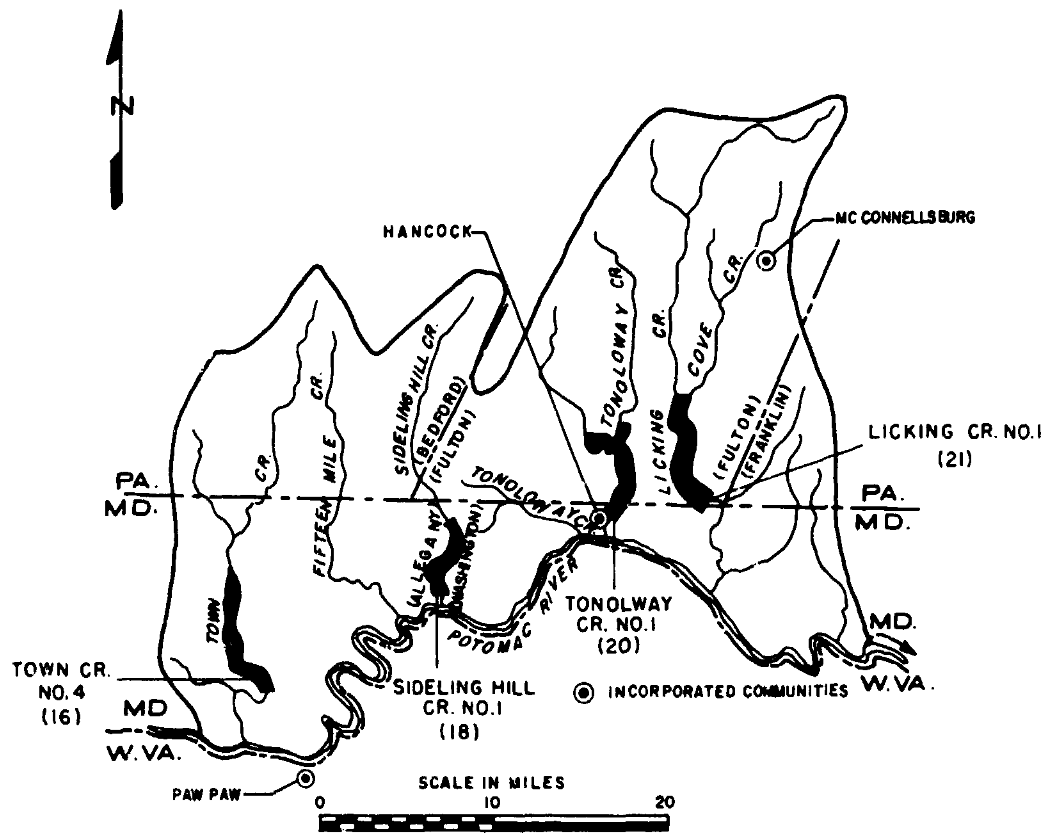


POTOMAC DRAINAGE AREA

SUB - BASIN STUDY REGIONS

TOWN, SIDELING HILL, TONOLOWAY AND LICKING CREEKS

FIGURE 81



POTOMAC SUB-TRIBUTARIES

TOWN, SIDELING HILL, TONOLOWAY AND LICKING BASINS
PROPOSED RESERVOIR SITES

FIGURE 82

pool would be 595 feet with a maximum water surface elevation of 615 feet. The reservoir would be 7.3 miles long, covering an area of 910 acres. There is no significant development in the reservoir area.

The site on Tonoloway Creek is located 1.4 miles above the mouth. The drainage area is 112 square miles, and the valley width at the site is 2,330 feet. The elevation of the conservation pool would be 503 feet with a maximum water surface elevation of 523 feet. The reservoir would be 8.0 miles long and would cover an area of 1,520 acres. No significant development exists in the reservoir area.

The Licking Creek site is located immediately upstream from Stone Bridge Church on the Pennsylvania-Maryland boundary. The drainage area is 158 square miles and the valley at the site is 1,170 feet wide. The elevation of the conservation pool would be 556 feet with a maximum water surface elevation of 576 feet. The reservoir would be 8.5 miles long, covering an area of 1,660 acres. No significant development exists in the reservoir area.

PRESENTATION OF DATA

POPULATIONS - PRESENT AND FUTURE

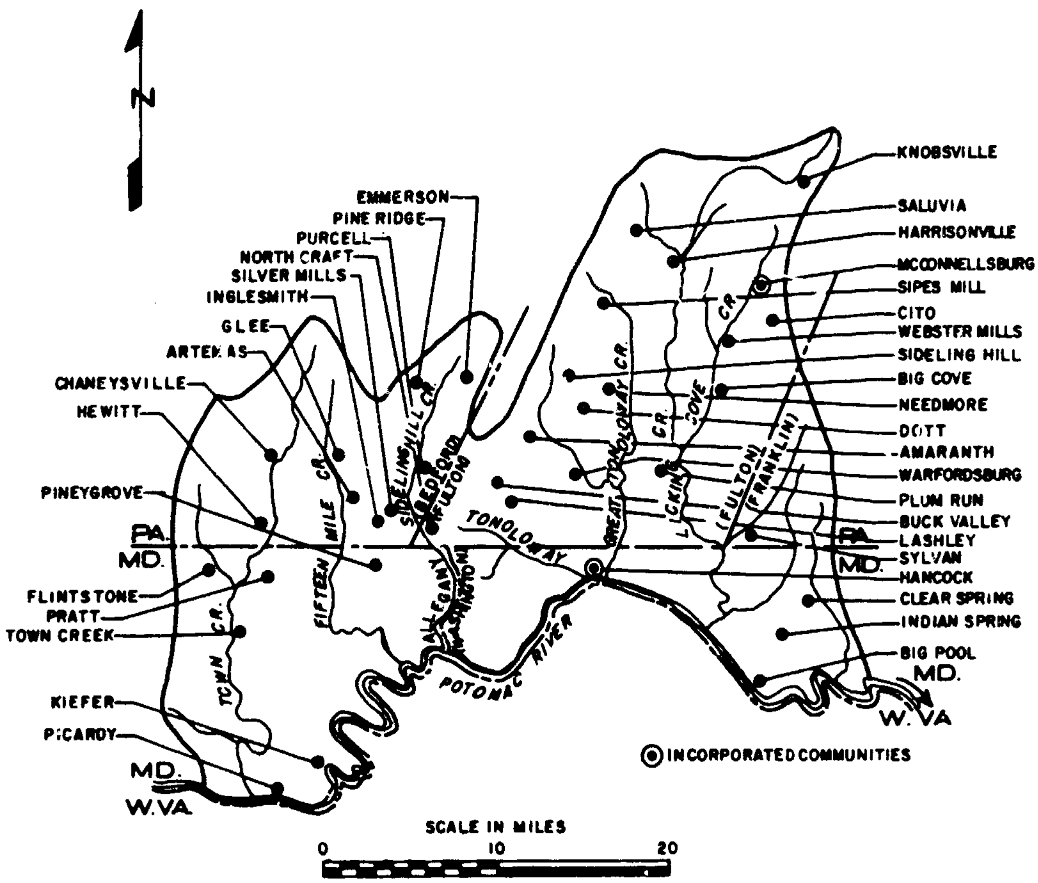
At the present time, approximately 12,300 persons reside in the Town, Sideling Hill, Tonoloway, and Licking Creek Basin area, constituting about one-seventieth of the Upper Potomac Basin populations. About 2,600 persons or 21 per cent of all persons residing in these basin areas are located in urban or incorporated communities (see Figure 83). About 61 per cent of the urban population in the four basins reside in the Licking Creek area.

It is estimated that by the years 1985 and 2010, the populations in these four basins will be about 18,900 and 25,200, respectively (see Table 50). Urban populations by the years 1985 and 2010 will have increased to about 5,500 and 9,100, respectively.

The locations of major population centers for which projected water supply and waste source information is desired are shown in Figure 84. Table 51 shows the percentage breakdown of county populations expected to form the nucleus of these development centers.

WATER SUPPLY REQUIREMENTS

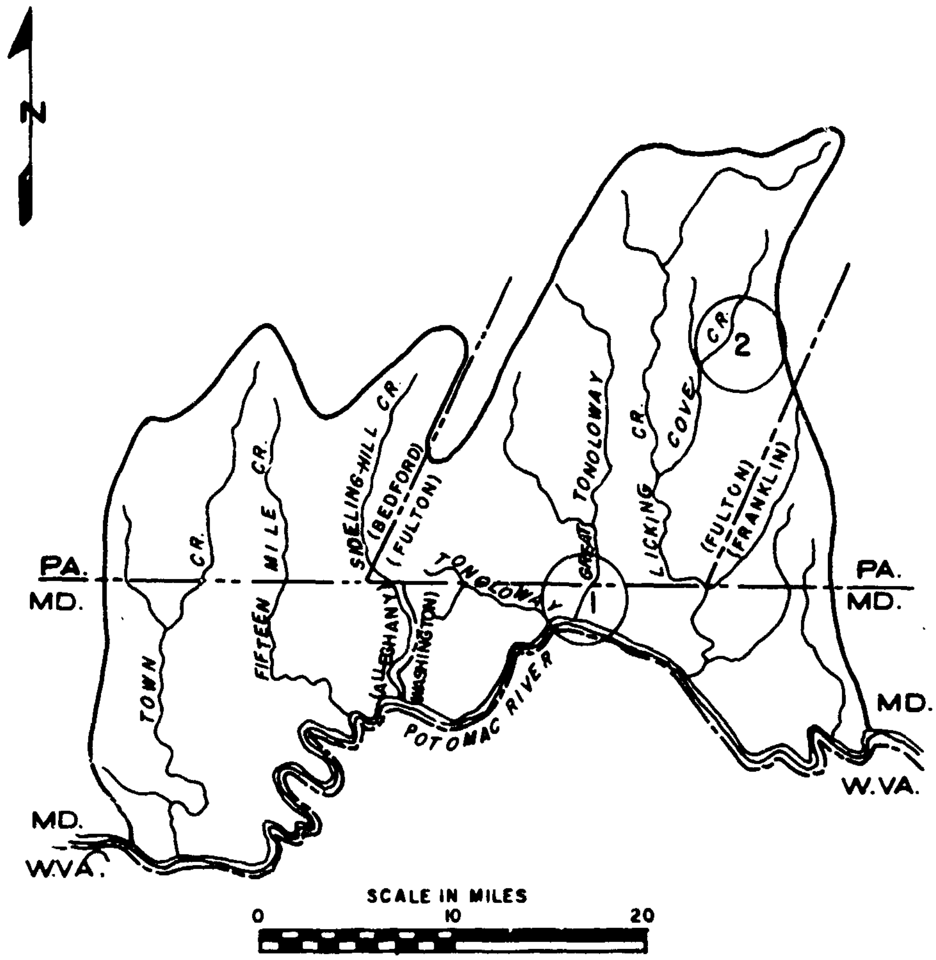
Urban populations and associated rural residential population projections for water use centers located within proximity or downstream from major reservoirs are shown in Table 52. It is noted that only one area is of significance in this regard. The projected average and maximum daily municipal - district water supply requirements obtained by applying the per capita daily rates for this area



POTOMAC SUB BASIN AREA

TOWN, SIDELING HILL, TONOLOWAY AND LICKING BASINS
STATES, COUNTIES AND COMMUNITIES

FIGURE 83



POTOMAC SUB-BASIN AREA

TOWN, SIDELING HILL, TONOLOWAY AND LICKING BASINS
DEVELOPMENT CENTERS

FIGURE 84

Table 50

Town, Sideling Hill, Tonoloway and Licking Basins

Populations by Counties and Residence Categories

County and State	% in Basin	Total	Farm	Non-Farm Residential	Non-Farm Small Town	Non-Farm Urban
			1960			
Washington, Md.	2	1,800	145	550	95	1,010
Fulton, Pa.	100	10,500	4,300	4,500	100	1,600
Totals		12,300	4,445	5,050	195	2,610
			1985			
Washington, Md.	2	2,845	125	820	120	1,780
Fulton, Pa.	100	16,000	3,700	8,200	400	3,700
Totals		18,845	3,825	9,020	520	5,480
			2010			
Washington, Md.	2	4,280	115	1,120	145	2,900
Fulton, Pa.	100	20,900	3,200	10,600	900	6,200
Totals		25,180	3,315	11,720	1,045	9,100

Table 51

Town, Sideling Hill, Tonoloway, and Licking Basins

Population Subdivisions

Subdivision Number	Location of Subdivision Sub-Basin	County	% County Population
Sub. No. 1	Potomac River	Washington, Md.	2
Sub. No. 2	Upper Licking River	Fulton, Pa.	100

Table 52

Populations Served by Central Water Supply Systems
in Vicinity and Downstream of Major Reservoirs

Sub-Basin and Identifying Community	Subdivision Number	Subdivision Populations 1960	1985	2010
Potomac River Hancock, Md.	1			
Rural Residential		140	410	845
Urban		1,010	1,780	2,900
Total		1,150	2,190	3,745

Note: Subdivision No. 2 not within reasonable proximity of major reservoir.

are shown in Table 53. It can be seen by inspection of supply requirements relative to the dependable stream flows in Table 53 where water storage benefits may or may not accrue.

QUALITY CONTROL REQUIREMENTS

In Table 54 are shown the projected waste loads, upstream residuals, and design loads for the stream and waste receiving flows required to maintain the objective for water quality. The waste loads or population equivalents (P.E.) of BOD_5 constitute an estimate of residual materials contained in treatment plant effluent received in local and upstream reaches. The design P.E.'s for the stream reach represent associated stream assimilative capacities originating from computations involving deoxgenation and reaeration velocity constants obtained from stream sampling in these areas. Points at which samples were collected are shown in Figure 85; data are appended to the December 1959 Potomac River Basin Study Report.

The requirements for quality control and the design minimum 7-day, 10-year return flows shown in Table 54 may be compared for purposes of determining possible need and amount of increased stream flow required to meet objectives.

MAJOR RESERVOIRS - WATER SUPPLY AND QUALITY CONTROL

Discussion on water quality and sanitation relative to possible reservoir sites in the Potomac Basin are given on pages 61-71 of the December 1959 Potomac River Basin Study Report. Discussions on the four reservoir sites now under consideration in this study region are given on pages 67-70 of the December 1959 report as follows:

	Number (Present)
1. Town Creek, Maryland, Site No. 4	16
2. Sideling Hill Creek, Maryland, Site No. 1	18
3. Tonoloway Creek, Maryland, and Pennsylvania, Site No. 1	20
4. Licking Creek, Pennsylvania, Site No. 1	21

To determine whether or not stored water could be utilized and therefore be assigned a benefit for water supply and pollution abatement purposes, the requirements, where waters are removed and returned as waste, are added together and compared with recorded minimum or statistical design minimum flows. Table 55 shows the total requirement with design minimum flows included as a means of determining needs for the utilization of stored water.

Table 53

Town, Sideling Hill, Tonoloway, and Licking Basins

Municipal Water Supply Requirements Relative to Dependable Surface Water Supply

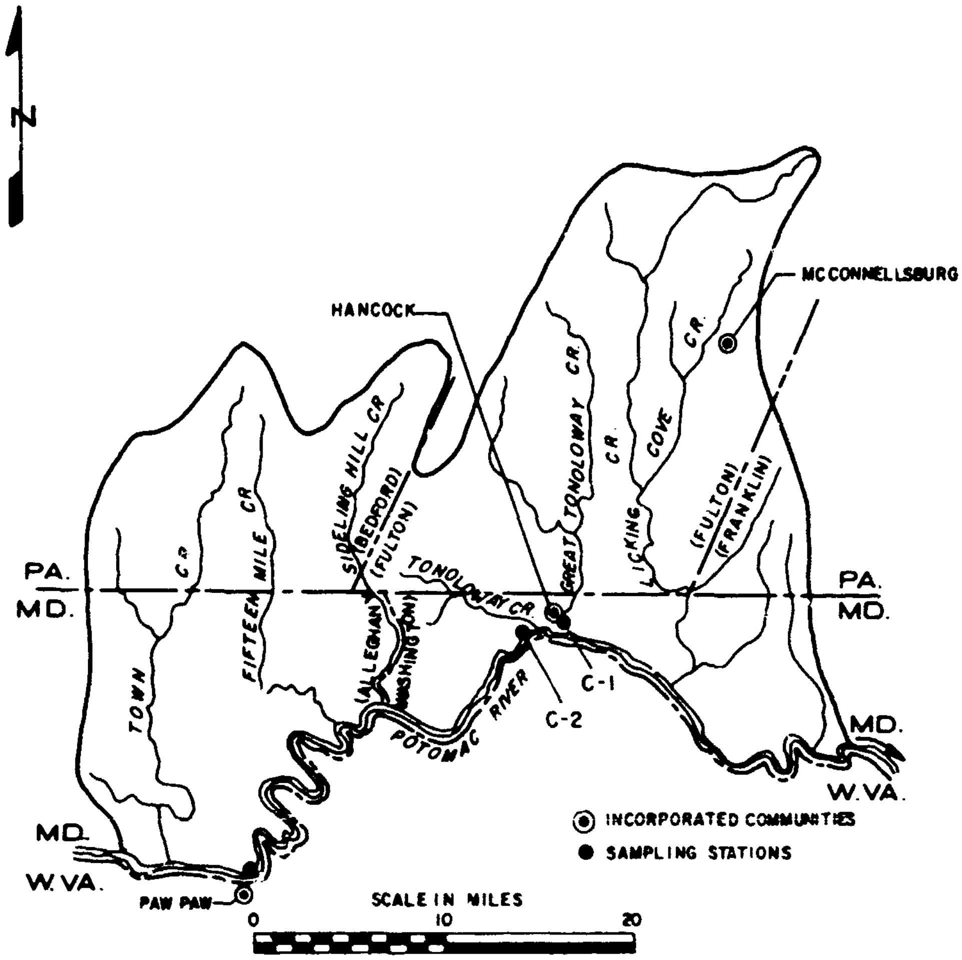
Sub-Basin Identifying Community	Subdivision Number	Million Gallons Per Day 1960	1985	2010
Potomac River	1			
Hancock, Md.				
Populations Served		1,150	2,190	3,745
Per Capita Daily Gal.				
Average		400	550	700
Maximum		600	750	900
Requirement MGD				
Average		0.46	1.20	2.62
Maximum		0.69	1.65	3.37
Surface Supply MGD(1)		187	187	187

(1) Potomac River - 185 MGD
Tonoloway Creek - 2 MGD

Table 54

Flow Requirement for Pollution Abatement
D.O. Objective - 5 ppm at 26°C

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
Potomac River	1			
Hancock Reach				
P.E. Received				
Maryland		285	440	560
West Virginia		1,200	1,685	2,115
Upstream Residual		5,500	9,750	14,000
Total Received		6,985	11,875	16,675
Design P.E. per cfs		162	162	162
cfs Required		43	73	103
7-day, 10-year cfs		322	322	322



POTOMAC SUB-TRIBUTARIES

TOWN, SIDELING HILL, TONOLOWAY AND LICKING BASINS
SAMPLING STATIONS LOCATIONS
PHS SURVEY 1958

FIGURE 85

Table 55

Town, Sideling Hill, Tonoloway, and Licking Basins

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Potomac River								
Hancock, Md.		43		73		103	285	322
Municipal								
Average	0.7		1.9		4.0			
Maximum	1.1		2.6		5.2			
Total								
Average	43.7		74.9		107.0			
Maximum	44.1		75.6		108.2			
Total Required	44.1		75.6		108.2			

Remarks - no storage benefits; possible municipal and industrial water supply to Berkeley Springs from this reach. Possible direct waste effluent discharge from Berkeley Springs area to this reach. No storage benefit with Berkeley Springs water and waste in this reach.

A supplemental report devoted strictly to benefit analyses will include detailed studies on storage benefits in this and all other downstream study areas.

CONOCOCHEAGUE AND ANTIETAM CREEK BASINS

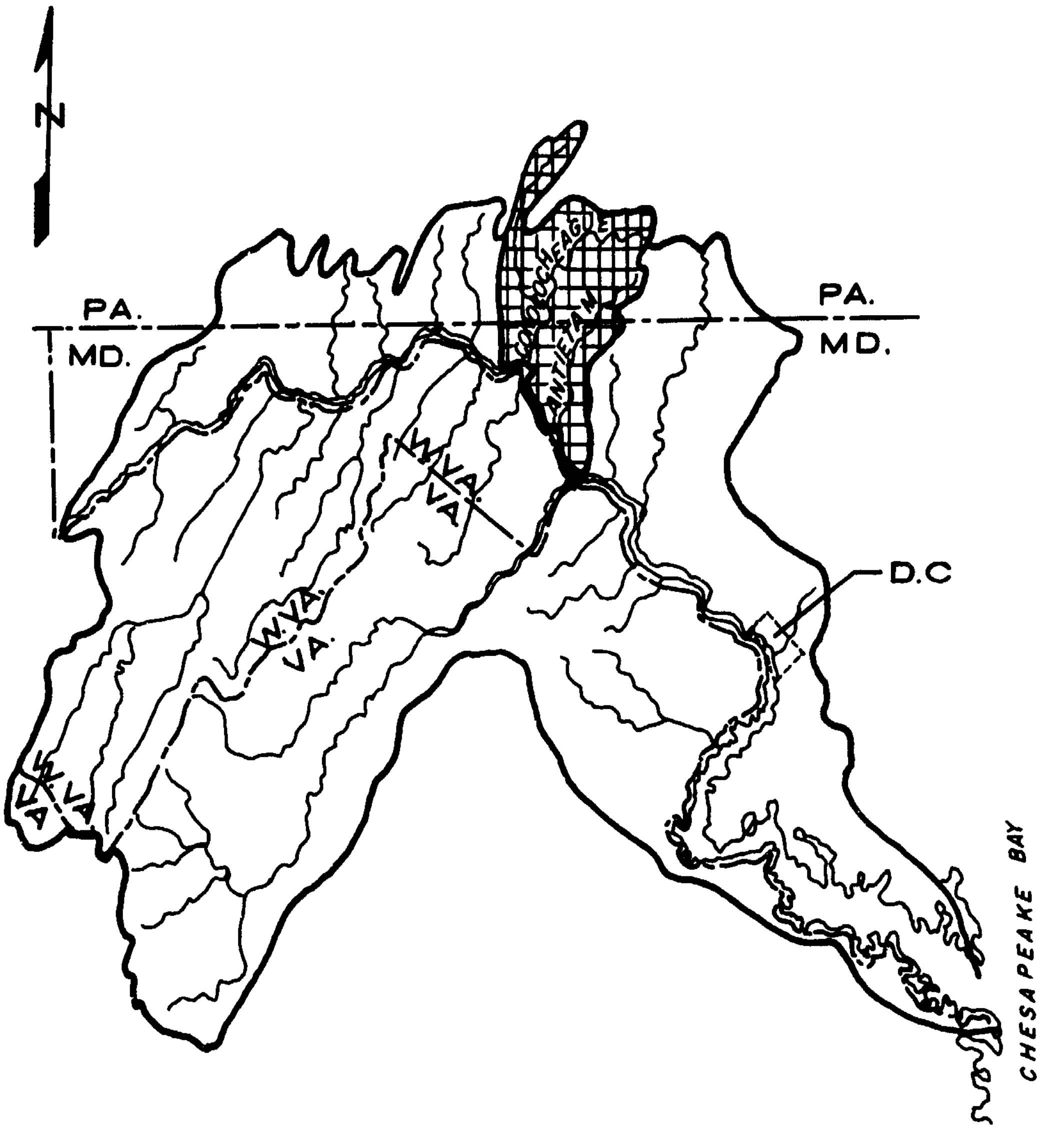
DESCRIPTION OF AREA AND MAJOR RESERVOIRS

The Conococheague Creek and Antietam Creek Basins comprise a portion of the Great Valley area located in Maryland and Pennsylvania. The total land area encompassed by these sub-basins of the Potomac is 855 square miles of which 603 square miles are located in most of Franklin County and part of Adams County, Pennsylvania, and 252 square miles in a portion of Washington County, Maryland. In drainage area, Conococheague Creek Basin is the sixth largest sub-basin of the Potomac, exceeded in size by the Shenandoah, South Branch Potomac, North Branch Potomac, Monocacy, and Cacapon River Basins.

Conococheague Creek enters the Potomac River at Williamsport, Maryland, 211 river miles upstream from the mouth of the Potomac at Chesapeake Bay and 100 river miles above Washington, D. C. Antietam Creek enters the Potomac near Sharpsburg, Maryland, 180 river miles from the mouth of the Potomac at Chesapeake Bay and 70 river miles above Washington, D. C. From the upper to lower elevations, these basins are oriented lengthwise in a southwesterly position, with Conococheague Basin extending about 75 miles northeasterly from the Potomac River and Antietam Creek Basin extending in the same direction from the Potomac about 50 miles (see Figure 86).

Conococheague Creek rises near South Mountain in Adams County, Pennsylvania, and flows westerly in a winding course to Chambersburg, Pennsylvania. From Chambersburg, it flows southwest to Williamson, Pennsylvania, where it winds in a southerly course to the Potomac. Antietam Creek is formed at the confluence of the East and West Branches of Antietam Creek, 1.5 miles southwest of Waynesboro, Pennsylvania. The West Branch rises near Mont Alto in Franklin County, Pennsylvania; the East Branch rises near South Mountain Sanitorium in Adams County, Pennsylvania. Antietam Creek flows southwest from Waynesboro to Hagerstown, Maryland, then south to the Potomac, 5 miles below Sharpsburg, Maryland.

The topography at the headwaters of Conococheague Creek is mountainous, and lower sections are characterized by rolling hills. Most of the tributaries are from the west, many flowing through broad valleys and open farm land. Antietam Creek is of the meandering type, flowing through rolling hill and wide valley country. Much of the area through which Antietam and Conococheague Creeks flow is composed of rich agricultural land.



POTOMAC DRAINAGE AREA

SUB - BASIN STUDY REGIONS
CONOCOCHEAGUE AND ANTIETAM CREEKS

FIGURE 86

For 30 years (1928-1958) of stream gaging at Fairview, Maryland (drainage area - 494 square miles), the average flow of Conococheague Creek has been 578 cubic feet per second (cfs), with extremes of 17,100 cfs and 25 cfs. For 30 years (1928-1958) of stream gaging near Sharpsburg, Maryland (drainage area - 281 square miles), the average flow of Antietam Creek has been 261 cfs, with extremes of 12,600 cfs and 50 cfs.

Three reservoir sites are under consideration in those tributary regions of the Potomac. All the sites are located in the Conococheague Creek Valley; one each on the West Branch, Back Creek, and Upper Main Stem of the Conococheague. (see Figure 87).

The proposed West Branch Conococheague reservoir site is located 5 miles north of Fort Loudon, Pennsylvania. The drainage area at the site is 78 square miles and the valley is 1,700 feet wide. The elevation of the conservation pool would be 737 feet with maximum water surface elevation at 758 feet. The reservoir would be 9 miles long and would cover 1,930 acres. The community of Metal, Pennsylvania, and the Mountain Lake Reservoir lie within the reservoir area.

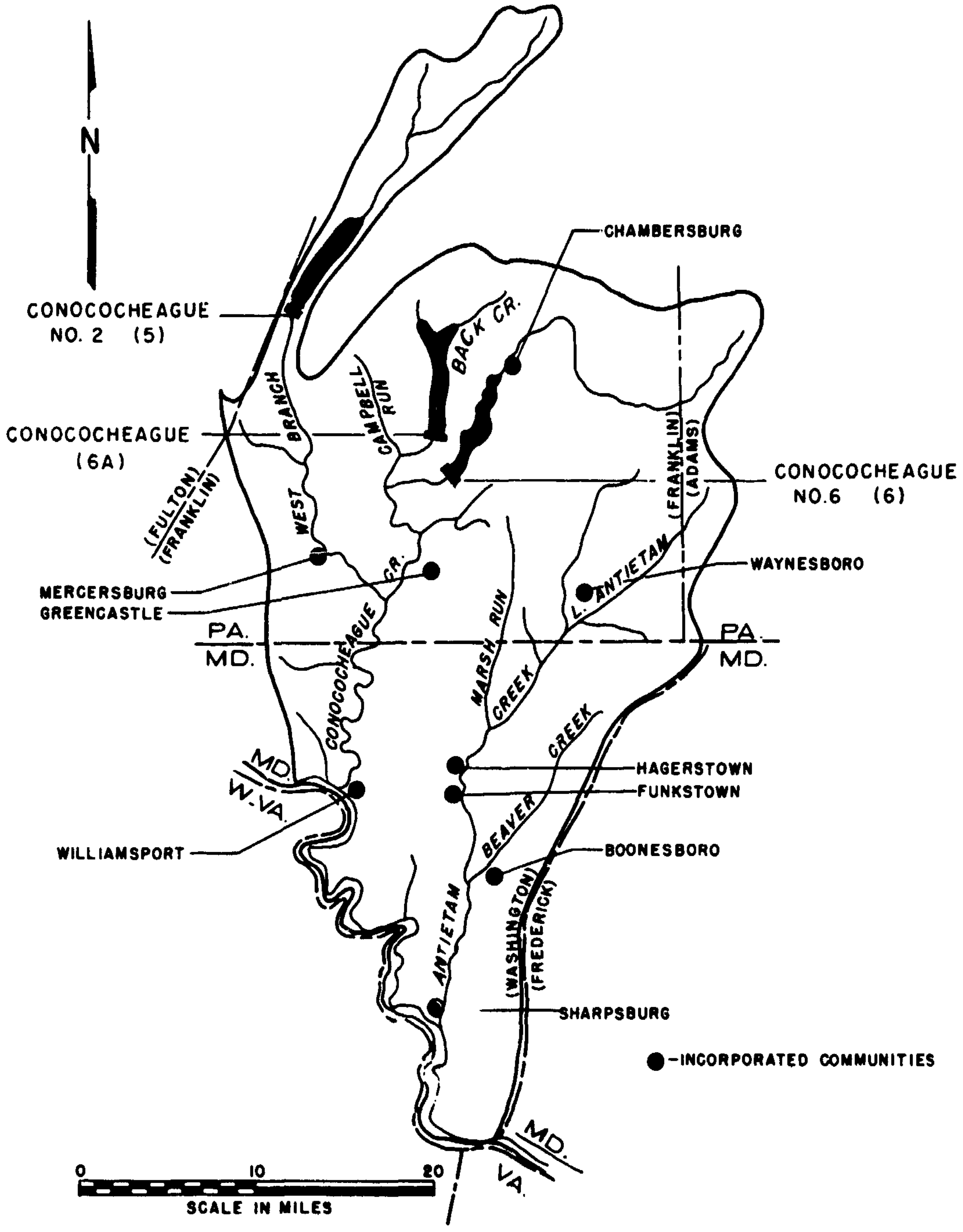
The Back Creek site is located approximately 6 miles southwest of Chambersburg, Pennsylvania, 5.6 miles upstream from Williamson, Pennsylvania. The drainage area is 63 square miles and the width of the valley at the site is 630 feet. The elevation of the conservation pool would be 549 feet with maximum water surface at 566 feet. The reservoir would be about 5.7 miles long and would cover 1,105 acres.

The upper main stem Conococheague Creek reservoir site is located 6.7 miles southwest of Chambersburg, Pennsylvania, and 1.5 miles due west of Marion, Pennsylvania. The drainage area is 142 square miles and the valley width at the site is 2,800 feet. The elevation of the conservation pool would be 575 feet with maximum water surface at 565 feet. The reservoir would be 6.5 miles long and would cover 1,180 acres.

PRESENTATION OF DATA

POPULATIONS - PRESENT AND FUTURE

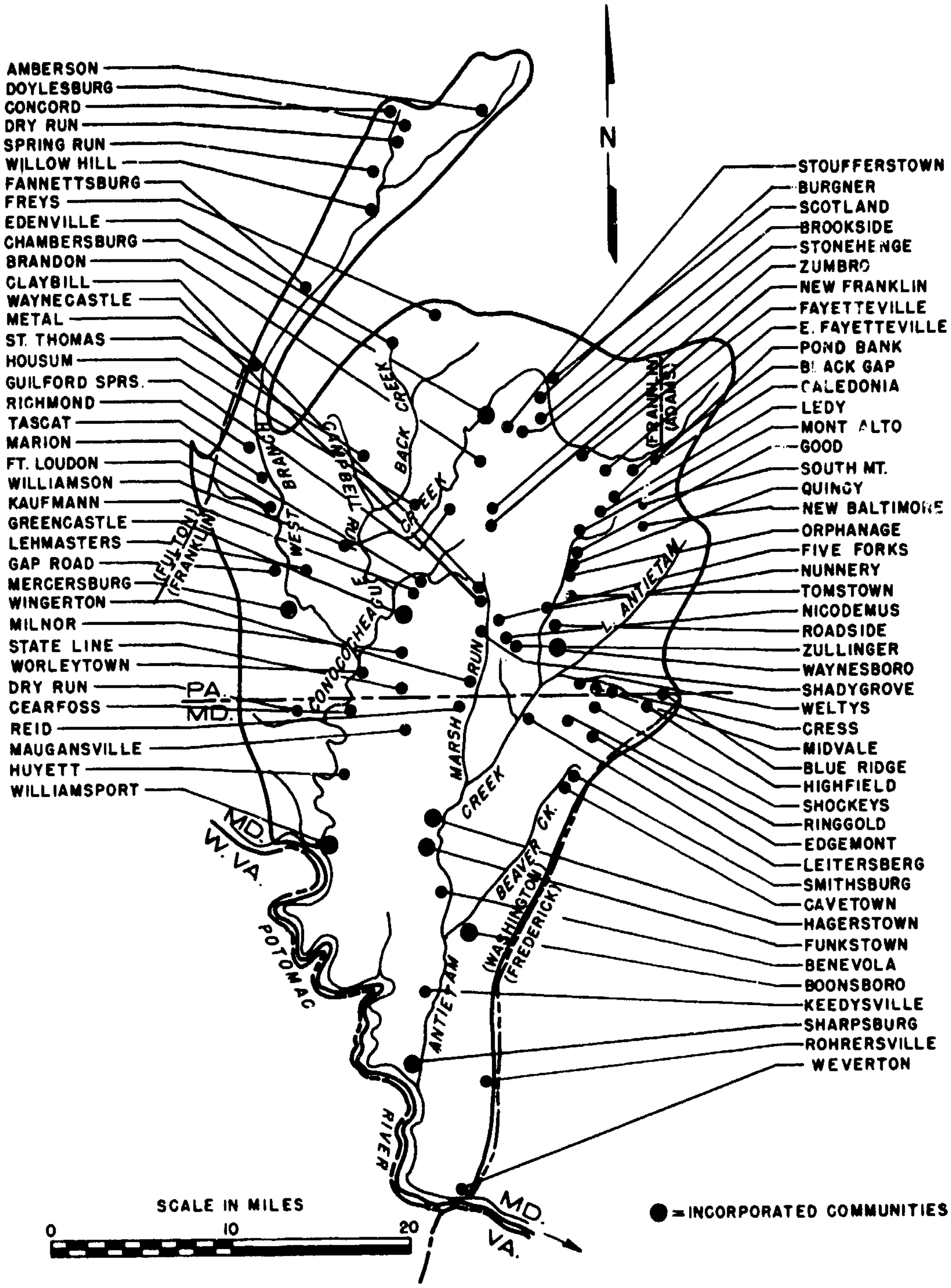
At the present time, approximately 175,700 persons reside in the Conococheague and Antietam Creek Basin area, constituting about one-fourth of the Upper Potomac Basin populations. About 88,500 persons or 50 per cent of all persons residing in these basin areas are located in urban or incorporated communities (see Figure 88). About 64 per cent of the urban populations in the two basins reside in the Antietam Creek area.



POTOMAC SUB-TRIBUTARIES

CONOCOCHEAGUE AND ANTIETAM CREEKS
PROPOSED RESERVOIR SITES

FIGURE 87



POTOMAC SUB-BASIN AREA

CONOCOCHEAGUE AND ANTIETAM BASINS STATES, COUNTIES AND COMMUNITIES

FIGURE 88

It is estimated that by the years 1985 and 2010, the population in these two basins will be 274,000 and 404,000, respectively (see Table 56). Urban populations by the years 1985 and 2010 will have increased to 151,200 and 239,000, respectively.

The locations of major population centers for which projected water supply and waste source information is desired are shown in Figure 89. Table 57 shows the percentage breakdown of urban county populations expected to form the nucleus of these development centers.

WATER SUPPLY REQUIREMENTS

Urban populations and associated rural residential populations projected for water use centers located within proximity or downstream from major reservoirs are shown in Table 58. The projected average and maximum daily municipal - district water supply requirements obtained by applying per capita daily rates shown in Table 59 to these area populations are given in Table 60.

The self-supplied industrial processing requirements shown for Subdivision No. 2 represent an annual increase of 6 percent from 1960 uses based on Office of Business Economics employment projections for chemical processing industries. For Subdivision No. 3, the self-supplied industrial processing requirement represents an annual increase of 8 per cent and 4 per cent for paper industries and miscellaneous industries, respectively. Cooling water requirements are based on estimated cooling needs associated with industrial processes and power demand potentials.

Areas where water storage benefits may or may not accrue can be determined by inspection of supply requirements relative to the dependable stream flows.

QUALITY CONTROL REQUIREMENTS

In Table 61 are shown the projected waste loads and design loads for the stream and waste receiving flows required to maintain quality objectives in stream reaches downstream from major reservoirs. The waste loads or P.E.'s of BOD_5 shown in Table 61 constitute an estimate of residual materials contained in projected municipal and/or industrial treatment plant effluents. Design P.E.'s for the particular stream reaches represent associated assimilative capacities originating from computations involving deoxygenation and reaeration velocity constants obtained from stream sampling in these areas. Points at which samples were collected are shown in Figure 90, the data for which are appended to the December 1959 Potomac River Basin Study Report corresponding to Stations: E-4, E-3, E-2, E-5, E-6, E-7, C-8, C-2, E-1, and C-7.

The requirements for quality control and design minimum 7-day, 10-year return flows shown in Table 61 may be compared for purposes of determining locations of need and amounts of increased stream flow required to meet objectives.

Table 56

Conococheague and Antietam Basins

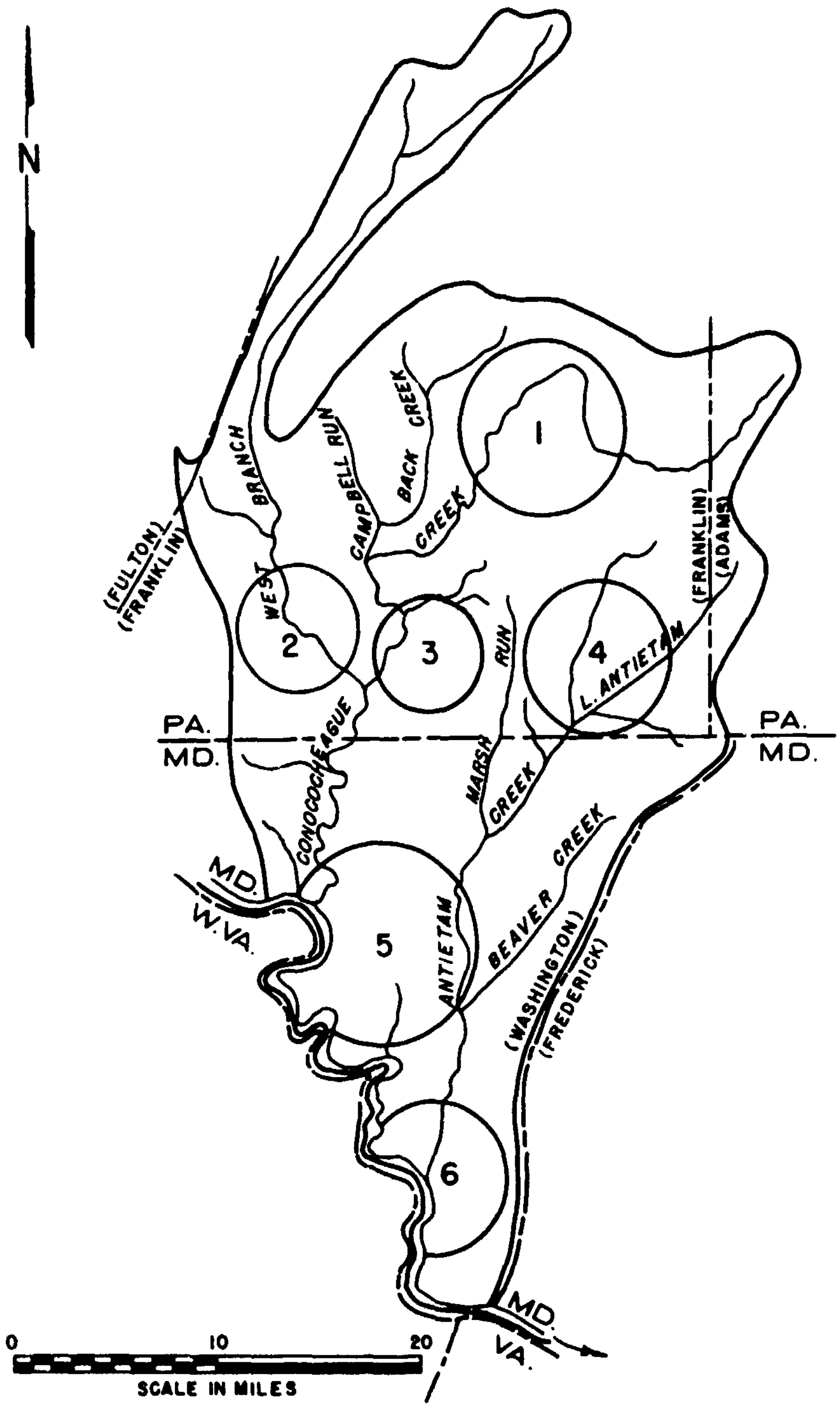
Populations by Counties and Residence Categories

County and State	% in Basin	Total	Farm	Non-Farm Rural Residential	Non-Farm Small Town	Non-Farm Urban
			1960			
Washington, Md.	98	88,395	7,055	27,050	4,700	49,590
Franklin, Pa.	100	87,300	11,000	35,000	2,400	38,900
Totals		175,695	18,055	62,050	7,100	88,490
			1985			
Washington, Md.	98	140,040	6,175	40,180	5,880	87,805
Franklin, Pa.	100	133,500	10,100	56,300	3,700	63,400
Totals		273,540	16,275	96,480	9,580	151,205
			2010			
Washington, Md.	98	209,720	5,585	54,980	7,055	142,100
Franklin, Pa.	100	194,310	8,600	83,300	5,500	96,910
Totals		404,030	14,185	14,185	138,280	239,010

Table 57

Population Subdivisions

Subdivision Number	Location of Subdivision Sub-Basin	Location of Subdivision County	% County Population
Sub. No. 1	Upper Conococheague	Franklin, Pa.	60
Sub. No. 2	Middle Conococheague	Franklin Co., Pa.	3
Sub. No. 3	Middle Conococheague	Franklin Co., Pa.	12
Sub. No. 4	Upper Antietam Creek	Franklin, Pa.	25
Sub. No. 5	Potomac River	Washington, Md.	93
Sub. No. 6	Potomac River	Washington, Md.	5



POTOMAC SUB-BASIN AREA

CONOCOCHEAGUE AND ANTIETAM BASINS
DEVELOPMENT CENTERS

FIGURE 89

Table 58

Populations Served by Central Water Supply Systems in Vicinity and Downstream of Major Reservoirs

Sub-Basin and Identifying Community	Subdivision Number	Subdivision Populations 1960	1985	2010
Upper Conococheague Chambersburg, Pa.	1			
Rural Residential		5,025	16,890	38,000
Urban		23,340	38,040	58,140
Total Served		28,365	54,930	96,140
Middle Conococheague Mercersburg, Pa.	2			
Rural Residential		265	850	1,900
Urban		1,165	1,900	2,900
Total Served		1,430	2,750	4,800
Middle Conococheague Greencastle, Pa.	3			
Rural Residential		1,050	3,375	7,585
Urban		4,670	7,610	11,365
Total Served		5,720	10,985	19,220
Upper Antietam Creek Franklin, Pa. Waynesboro, Pa.	4			
Rural Residential		2,180	7,040	15,800
Urban		9,725	15,850	24,225
Total Served		11,905	22,890	40,025
Potomac River Washington, Md. Williamsport-Hagerstown, Md.	5			
Rural Residential		6,420	19,065	39,130
Urban		47,060	82,770	134,850
Total Served		53,480	101,835	173,980
Potomac River Washington, Md. Sharpsburg, Md.	6			
Rural Residential		345	1,025	2,105
Urban		2,530	4,450	7,250
Total Served		2,875	5,475	9,355

Note: Assumes Chambersburg wastes discharged downstream from major reservoir.

Table 59

Per Capita Daily Municipal - District Demand Rates

Sub-Basin and Identifying Community	Subdivision Number	Per Capita Daily Gal. 1960	1985	2010
Upper Conococheague Chambersburg, Pa.	1			
Average		96	132	168
Maximum		144	180	216
Middle Conococheague Mercersburg, Pa.	2			
Average		128	176	224
Maximum		192	240	288
Middle Conococheague Greencastle, Pa.	3			
Average		128	176	224
Maximum		192	240	288
Upper Antietam Creek Franklin, Pa. Waynesboro, Pa.	4			
Average		187	257	327
Maximum		280	350	420
Potomac River Washington, Md. Williamsport-Hagerstown, Md.	5			
Average		108	149	189
Maximum		162	203	243
Potomac River Washington, Md. Sharpsburg, Md.	6			
Average		59	81	103
Maximum		88	110	132

Table 60

Municipal Water Supply Requirements Relative
to Dependable Surface Water Supply

Sub-Basin and Identifying Community	Subdivision Number	Million Gallons Per Day 1960	1985	2010
Upper Conococheague	1			
Chambersburg, Pa.				
Municipal - District				
Average		2.7	7.3	16.1
Maximum		4.1	9.9	20.7
Cooling		[2.5]	[5.0]	[8.5]
Surface Supply		3.8	3.8	3.8
Middle Conococheague	2			
Mercersburg, Pa.				
Municipal - District				
Average		0.2	0.5	1.1
Maximum		0.3	0.7	1.4
Industrial Processing		0.3	0.8	1.5
Totals				
Average		0.5	1.3	2.6
Maximum		0.6	1.5	2.9
Surface Supply		5.2	5.2	5.2
Middle Conococheague	3			
Greencastle, Pa.				
Municipal - District				
Average		0.7	1.9	4.3
Maximum		1.1	2.6	5.5
Industrial Processing		2.3	5.8	9.5
Totals				
Average		3.0	7.7	13.8
Maximum		3.4	8.4	15.0
Cooling		[-]	[5.0]	[8.0]
Surface Supply		10.3	10.3	10.3
Upper Antietam	4			
Waynesboro, Pa.				
Municipal - District				
Average		2.2	5.9	13.1
Maximum		3.3	8.0	16.8
Surface Supply		.3	.3	.3

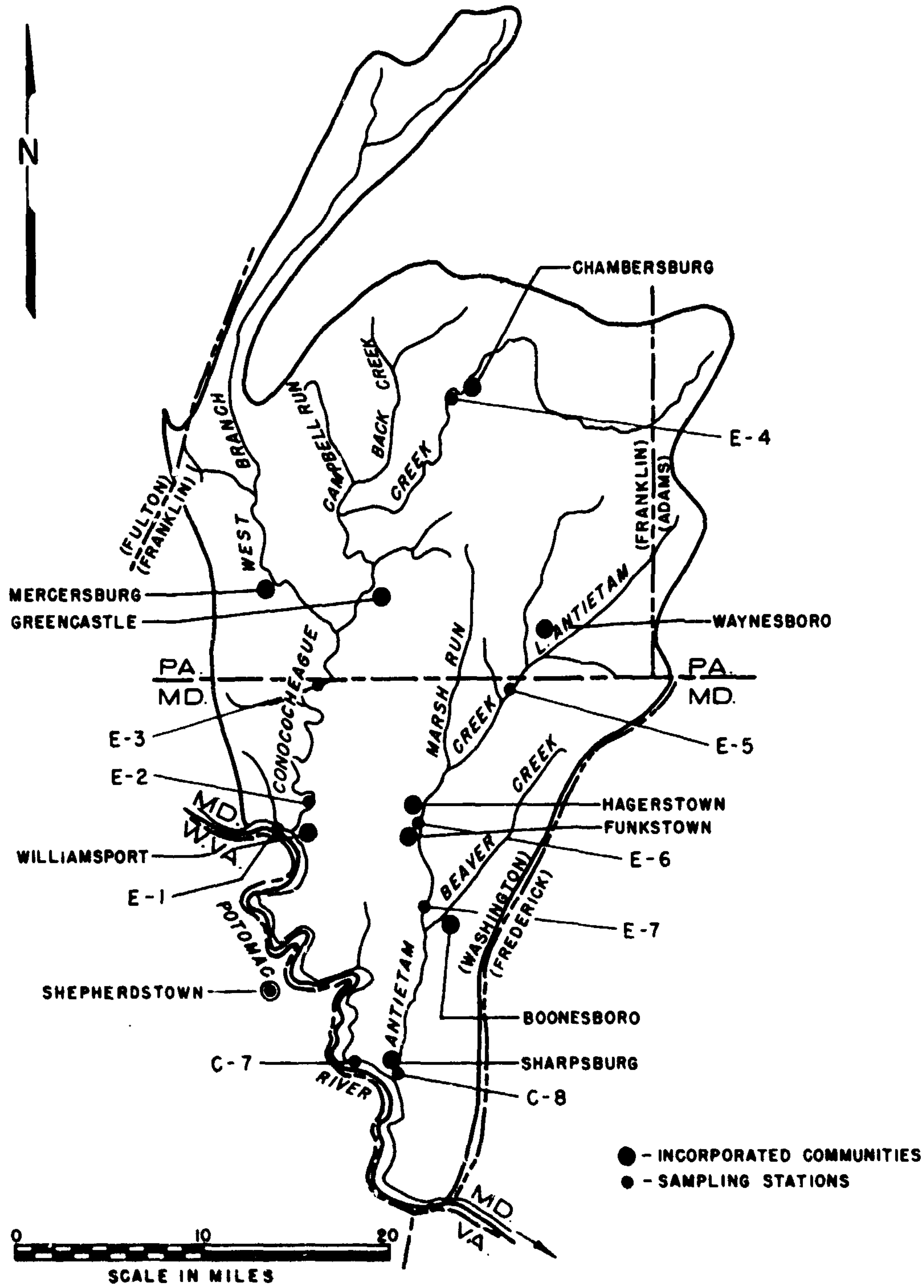
Table 60 (Continued)

Municipal Water Supply Requirements Relative to Dependable Surface Water Supply

Sub-Basin and Identifying Community	Subdivision Number	Million Gallons Per Day 1960	1985	2010
Potomac River				
Williamsport-Hagerstown, Md.	5			
Municipal - District				
Average		5.8	15.2	33.0
Maximum		8.7	20.7	42.0
Industrial Processing		.6	1.2	1.8
Total				
Average		6.4	16.4	34.8
Maximum		9.3	21.9	43.8
Cooling (1)		[205]	[233]	[263]
Surface Supply (2)		234	234	234

(1) Municipal Electric 1960 - 32 MGD
1985 - 60 MGD
2010 - 90 MGD

(2) Potomac - 198 MGD
Antietam - 36 MGD



POTOMAC SUB-TRIBUTARIES

CONOCOCHEAGUE AND ANTIETAM CREEKS
SAMPLING STATION LOCATIONS
PHS SURVEY 1958

FIGURE 90

Table 61

Flow Requirement for Pollution Abatement
D.O. Objective - 5 ppm at 26°C

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
Conococheague Creek Chambersburg Reach (1)	1			
P.E. Received		7,010	11,000	14,400
Design P.E. per cfs		175	175	175
cfs Required		40	63	82
7-day, 10-year cfs		12	12	12
Conococheague Creek Mercersburg Reach	2			
P.E. Received				
Municipal		355	550	720
Industrial		4,000	5,000	6,000
Total Received		4,355	5,550	6,720
Design P.E. per cfs		175	175	175
cfs Required		25	32	39
7-day, 10-year cfs		16	16	16
Conococheague Greencastle Reach	3			
P.E. Received				
Municipal		1,430	2,200	2,870
Industrial		1,250	3,520	4,900
Upstream Residual		4,560	7,150	9,360
Total Received		7,240	12,870	17,130
Design P.E. per cfs		175	146	92
cfs Required		41	88	186
7-day, 10-year cfs		30	30	30
Conococheague Creek Below confluence with W. Branch	3a			
Greencastle		6,150	11,000	14,560
Mercersburg		3,700	4,720	5,700
Total Residual		9,050	15,720	20,260
Design P.E. per cfs		175	146	92
cfs Required		56	107	220
7-day, 10-year cfs		51	51	51

Table 61 (Continued)

Flow Requirement for Pollution Abatement
D.O. Objective - 5 ppm at 26°C

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
Potomac River Williamsport Reach	5a			
P.E. Received				
Municipal		660	1,010	1,300
Industrial		8,000	11,000	14,000
Upstream Residual		4,300	7,350	10,300
Tributary Residual		5,500	8,800	11,345
Total Received		18,460	28,160	36,945
Design P.E. per cfs		162	162	162
cfs Required		114	173	228
7-day, 10-year cfs		425	425	425
Antietam Creek Waynesboro Reach	4			
P.E. Received		2,970	4,570	6,000
Design P.E. per cfs		162	162	162
cfs Required		18	28.5	37
7-day, 10-year cfs		1	1	1
Antietam Creek Hagerstown Reach	5			
P.E. Received		12,700	19,200	24,700
Upstream Residual		2,140	3,300	4,300
Total Received		14,840	22,500	29,000
Design P.E. per cfs		220	210	196
cfs Required		67	108	148
7-day, 10-year cfs		42	42	42
Potomac River Shepherdstown Reach	5b			
P.E. Received		1,020	1,545	1,920
Tributary Residual		17,770	25,780	33,100
Upstream Residual		12,400	20,200	26,000
Total Received		31,190	47,525	61,020
Design P.E. per cfs		140	140	140
cfs Required		222	340	435
7-day, 10-year cfs		455	455	455

(1) Assumes Chambersburg wastes discharged downstream from major reservoir.

MAJOR RESERVOIRS - WATER SUPPLY AND QUALITY CONTROL

Discussions on water quality and sanitation relative to possible reservoir sites are given on pages 61-64 of the December 1959 Potomac River Basin Study Report. The West Branch Conococheague site (Conococheague Creek Valley, West Branch Site 2 and present Site 5) is discussed on page 70 of that report.

The water quality of Conococheague Creek Valley, Back Creek Site 6A, is similar to Site 5 on the West Branch. No large population centers or potential pollution sources exist in the upstream area and the quality of the water should be suitable for water supply.

The main stem Conococheague Creek site now under consideration (Conococheague Site 6 and present Site 6) is subject to direct contamination by treated sewage and food processing effluents discharged at Chambersburg, Pennsylvania, (approximately 20,000 population). At a treatment efficiency of 85 per cent biochemical oxygen demand reduction, the municipal and industrial effluent loads discharged to the reservoir per day would be equivalent to raw waste loads from a population of approximately 6,000 persons. Although the reservoir would provide a stabilization medium for continued treatment of these wastes, it is aesthetically undesirable to use this reservoir as a source of raw water for conventional domestic treatment and use. Nutrient accumulations coupled with rising water temperatures during drought periods would further reduce water quality by promoting nuisance accumulations of filter-obstructing, taste and odor producing algae.

The City of Chambersburg, Pennsylvania, would be the most immediate potential user of water from this reservoir. New water sources and means of expanded existing supplies are being explored by this community. Until such time as all existing sources of water supply have been exhausted or unless waste effluents are diverted to below the dam, the use of this reservoir for water supply purposes could not be recommended. Diversion of wastes to a point below the dam would make this reservoir suitable for water supply purposes. Considerations relative to control of recreational uses of the reservoir would also be required.

The water released from the dam to downstream locations, after having undergone natural purification and conditioning in the open stream, could be used as a raw water supply. The fast growing community of Greencastle, Pennsylvania, now using a spring supply, and perhaps Waynesboro, Pennsylvania, presently using water from Little Antietam and Rattlesnake Creeks, could realize future benefits from an assured low flow increase in Conococheague Creek.

If Chambersburg treated waste effluents are not piped below the dam, a means should be provided whereby continuous mixing of bottom and surface water would be accomplished in order to assure a suitable environment for fish and other aquatic life within and downstream

from this reservoir. This would prevent depletion of dissolved oxygen and accumulation of toxic decomposition products in the lower and bottom areas of the reservoir.

This site would offer pollution abatement benefits by low flow augmentation at and below the confluence of the West Branch Conococheague Creek which receives municipal and industrial wastes from Mercersburg, Pennsylvania. Additional benefits could be realized at points further downstream including benefits from dilution and assimilation of domestic and industrial wastes discharged to the Conococheague and Potomac River at Williamsport, Maryland.

Assured increases in low flows from Conococheague Creek would improve the quality of Potomac River water and benefit the water supply at Washington, D. C.

To determine whether or not stored water could be utilized and therefore be assigned a benefit for water supply and pollution abatement purposes, the requirements where waters are removed and returned as waste are added together and compared with recorded minimum or statistical design minimum flows. Table 62 shows the total requirements with design minimum flows included as a means of determining needs for the utilization of stored water.

By transporting Chambersburg wastes to a point below the main stem reservoir, it would be possible to use this reservoir as a source of supply at Chambersburg, Greencastle, and perhaps Waynesboro. A supplemental report devoted to benefit analyses will include detailed studies on storage benefits in this sub-basin region and all downstream study areas.

SLEEPY, BACK, AND OPEQUON CREEK BASINS

DESCRIPTION OF AREA AND MAJOR RESERVOIRS

The Sleepy Creek, Back Creek, and Opequon Creek Basins comprise a portion of the Great Valley area located in Virginia and West Virginia. The total land area encompassed by these three sub-basins of the Potomac Basin is 761 square miles of which 422 square miles are located in Berkeley County and parts of Morgan and Jefferson Counties in West Virginia, and 339 square miles in Frederick and Clark Counties in Virginia.

Sleepy, Back, and Opequon Creeks parallel one another while flowing from the south to the Potomac River at river mileages above Washington, D. C., of 123, 116, and 92 miles, respectively.

From the upper to lower elevations, these basins are oriented lengthwise in a northeasterly position. Sleepy Creek Basin (143 square miles) extends southwesterly from the Potomac River about

Table 62

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Conococheague Creek								
Chambersburg, Pa.		40		63		82	6	12
Municipal								
Average	4.2		11.2		24.7			
Maximum	6.3		15.2		31.8			
Totals								
Average	44.2		74.2		106.7			
Maximum	46.3		78.2		113.8			
Cooling	[3.9]		[7.7]		[13.1]			
Total Required	44.2		74.2		106.7			
Increase Required	32.2		62.2		94.7			
Remarks - For use of Site 6 for water supply, Chambersburg waste effluent must be piped below dam. Chambersburg waste effluent (adjusted for losses) to be used as part of quality control flow required downstream at Greencastle.								
Conococheague Creek								
Mercersburg, Pa.		25		32		39	8	16
Municipal								
Average	0.4		0.9		2.1			
Maximum	0.6		1.3		2.7			
Industrial	0.5		1.3		2.3			
Totals								
Average	25.9		34.2		43.4			
Maximum	26.1		34.6		44.0			
Total Required	26.1		34.6		44.0			
Increase Required	10.1		18.6		28.0			
Remarks - storage benefits.								
Conococheague Creek								
Greencastle, Pa.		41		88		186	16	30
Municipal								
Average	1.1		2.8		6.2			
Maximum	1.6		3.9		8.0			
Industrial	3.6		9.0		14.6			
Total								
Average	45.7		99.8		206.8			
Maximum	46.2		100.9		208.6			
Cooling	[-]		[7.7]		[12.3]			
Total Required	46		101		209			
Increase Required	16		71		179			

Table 62 (Continued)

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.

Remarks - The increase required is based on Greencastle taking water supply from run of the river. If water supply is taken from the Main Stem reservoir, the increase required would be:

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
	11		58		157			
Conococheague Creek								
Below confluence with W. Branch								
Total Required	56		107		220		51	
Increase Required	5		56		169			
Potomac River								
Williamsport and Hagerstown, Md.		106		173		228	305	425
Municipal								
Average	8.9		23.4		51.0			
Maximum	13.4		31.8		64.8			
Total								
Average	122.9		196.4		279.0			
Maximum	127.4		204.8		292.8			
Cooling	[267]		[267]		[267]			
Total Required	127.4		204.8		292.8			

Remarks - No storage benefits; estimate 90 percent water supply diversion to Hagerstown area. Hagerstown waste effluents (adjusted for losses) returned to Potomac by way of Antietam Creek. Consumptive losses in upper basin water use areas not considered to significantly affect minimum flows.

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Antietam Creek								
Waynesboro, Pa.		18		28.5		37	-	1.0
Municipal								
Average	3.4		9.1		20.2			
Maximum	5.1		12.3		25.8			
Total								
Average	21.4		37.6		57.2			
Maximum	23.1		40.8		62.8			
Total Required	23.1		40.8		62.8			
Increase Required	22.1		39.8		61.8			

Table 62 (Continued)

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Antietam Creek								
Hagerstown, Md.		67		108		148	30	42
Municipal	Potomac		Potomac		Potomac			
Industrial	0.9		1.9		2.8			
Total		67.9		109.9		150.8		
Cooling	[49.5]		[92]		[138]			
Total Required		67.9		109.9		150.8		
Increase Required		25.9		67.9		108.8		

Remarks - storage benefits; could re-use waste effluent from Waynesboro as part of flow requirement for quality control, but not acceptable for water supply at Hagerstown.

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Potomac River								
Shepherdstown, W. Va.		222		340		435	302	455
Municipal								
Average	0.3		0.8		1.7			
Maximum	0.5		1.1		2.2			
Industrial	1.4		3.1		4.9			
Totals								
Average		223.7		343.9		441.6		
Maximum		223.9		344.2		442.1		
Total Required		223.9		344.2		442.1		

Remarks - storage benefits possible; consumption and diversion losses upstream would significantly reduce minimum flows.

25 miles; Back Creek Basin (273 square miles) extends about 55 miles; and Opequon Creek Basin (345 square miles) extends about 60 miles. All of these creeks have their sources in Virginia (see Figure 91).

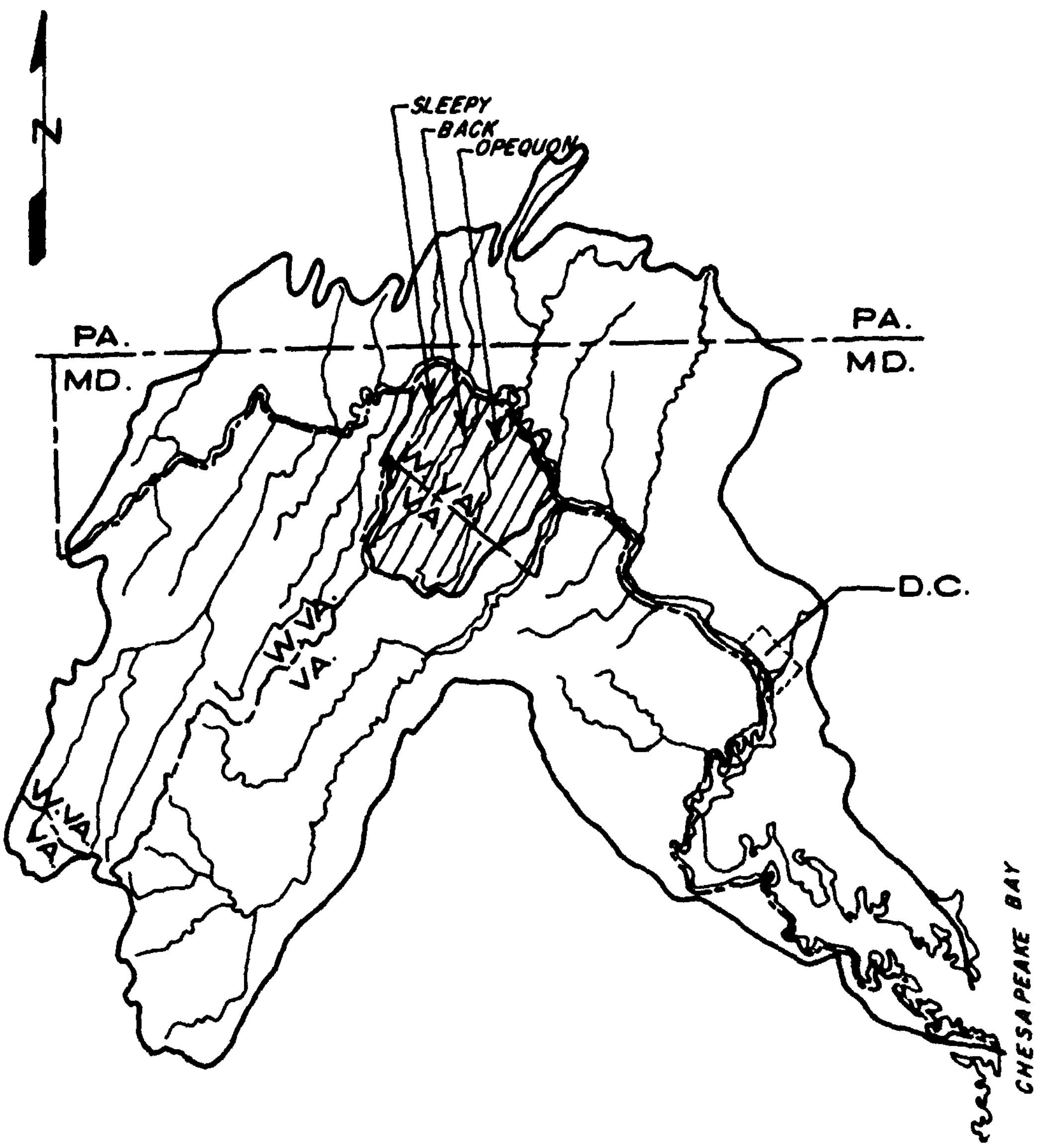
The watershed areas consist of wide valleys bordered by mountain ranges and foothills. The streams in the lower basin area meander through open farm land, and during rainy periods carry considerable amounts of silt and other runoff material to the Potomac River.

For 23 years (1928-1931 and 1938-1958) of stream gaging near Jones Springs, West Virginia (drainage area - 243 square miles), the average flow of Back Creek has been about 197 cubic feet per second, with extremes of 22,400 cfs and 0.9 cfs. For 11 years (1947-1958) of stream gaging near Martinsburg, West Virginia (drainage area - 272 square miles), the average flow of Opequon Creek has been 216 cfs, with extremes of 9,100 cfs and 25 cfs. No gaging records are available for Sleepy Creek.

Two reservoir sites are under consideration in these tributary regions of the Potomac River. One site is on Back Creek and the other in the upper Opequon Creek area (see Figure 92).

The reservoir site on Back Creek is located in the middle section of Back Creek Basin. The site is 2.2 miles south of Jones Springs, West Virginia, where the drainage area is 231 square miles and valley width 1,600 feet. The elevation of the conservation pool would be 529 feet and the maximum water surface elevation would be 551 feet. The reservoir would be 11 miles long and would cover 3,560 acres. The community of Shanghai, West Virginia, lies within the reservoir area.

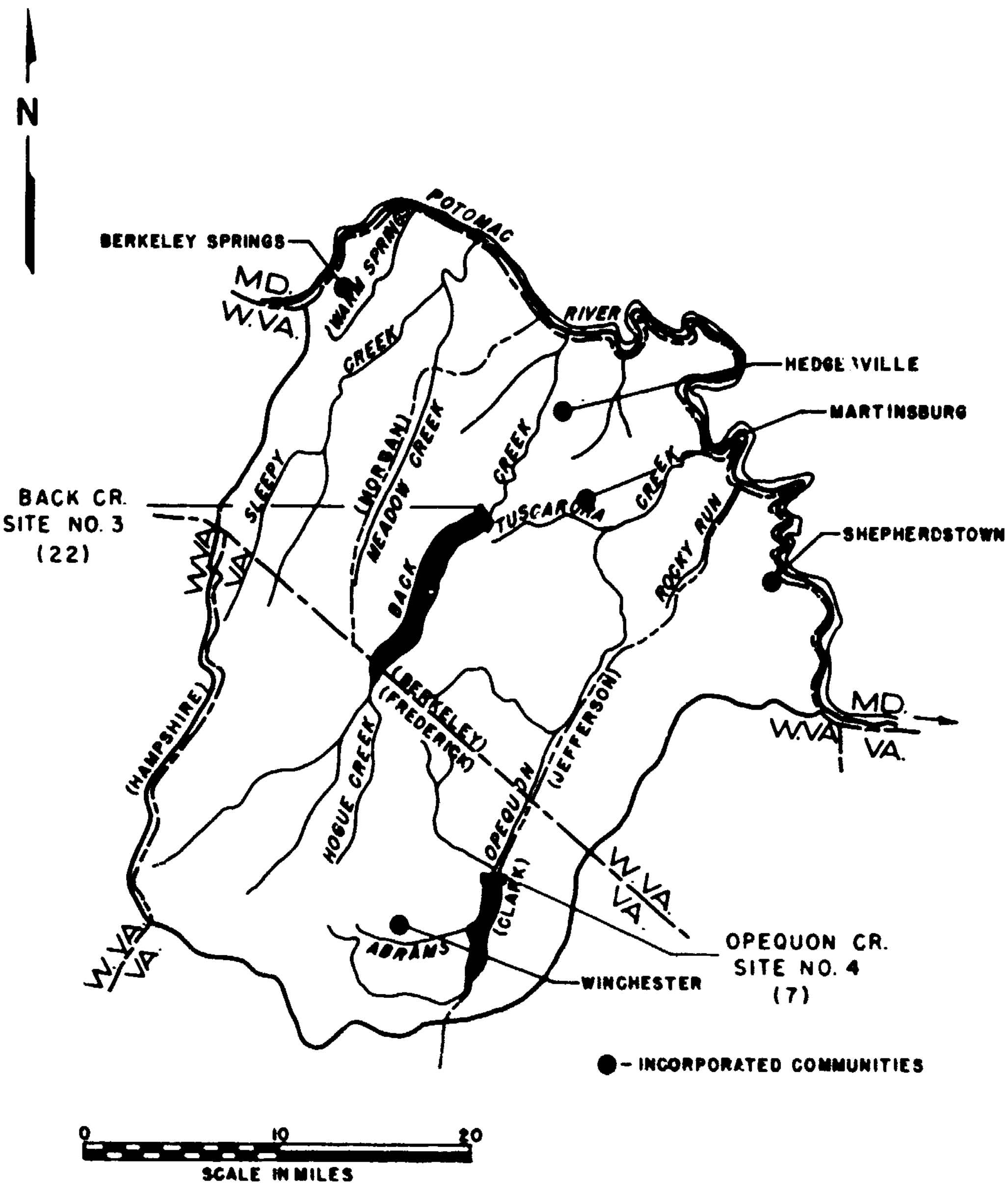
The reservoir site on Opequon Creek is located approximately 6 miles northeast of Winchester, Virginia, and 0.4 miles upstream from State Route 274 crossing of Opequon Creek. The drainage area is 121 square miles and the valley width at the site is 1,500 feet. The elevation of the conservation pool would be 524 feet with a maximum water surface elevation at 552 feet. The reservoir would be 4.5 miles long and would cover 1,100 acres.



POTOMAC DRAINAGE AREA

SUB-BASIN STUDY REGIONS
SLEEPY, BACK AND OPEQUON CREEKS

FIGURE 91



POTOMAC SUB-TRIBUTARIES

SLEEPY, BACK AND OPEQUON CREEKS PROPOSED RESERVOIR SITES

FIGURE 92

PRESENTATION OF DATA

POPULATIONS - PRESENT AND FUTURE

At the present time, approximately 81,000 persons reside in the Sleepy Creek, Back Creek, and Opequon Creek Basin area, constituting about one-tenth of the Upper Potomac Basin populations. About 36,500 persons or 45 per cent of all persons residing in these basin areas are located in urban or incorporated communities (see Figure 93). About 90 per cent of the urban population in the three basins reside in the Opequon Creek area.

It is estimated that by the years 1985 and 2010, the populations in these three basins will be 119,000 and 177,000, respectively (see Table 63). Urban populations by the years 1985 and 2010 will have increased to 60,000 and 102,000, respectively.

The locations of major population centers for which projected water supply and waste source information is desired are shown in Figure 94. Table 64 shows the percentage breakdown of urban county populations expected to form the nucleus of these development centers.

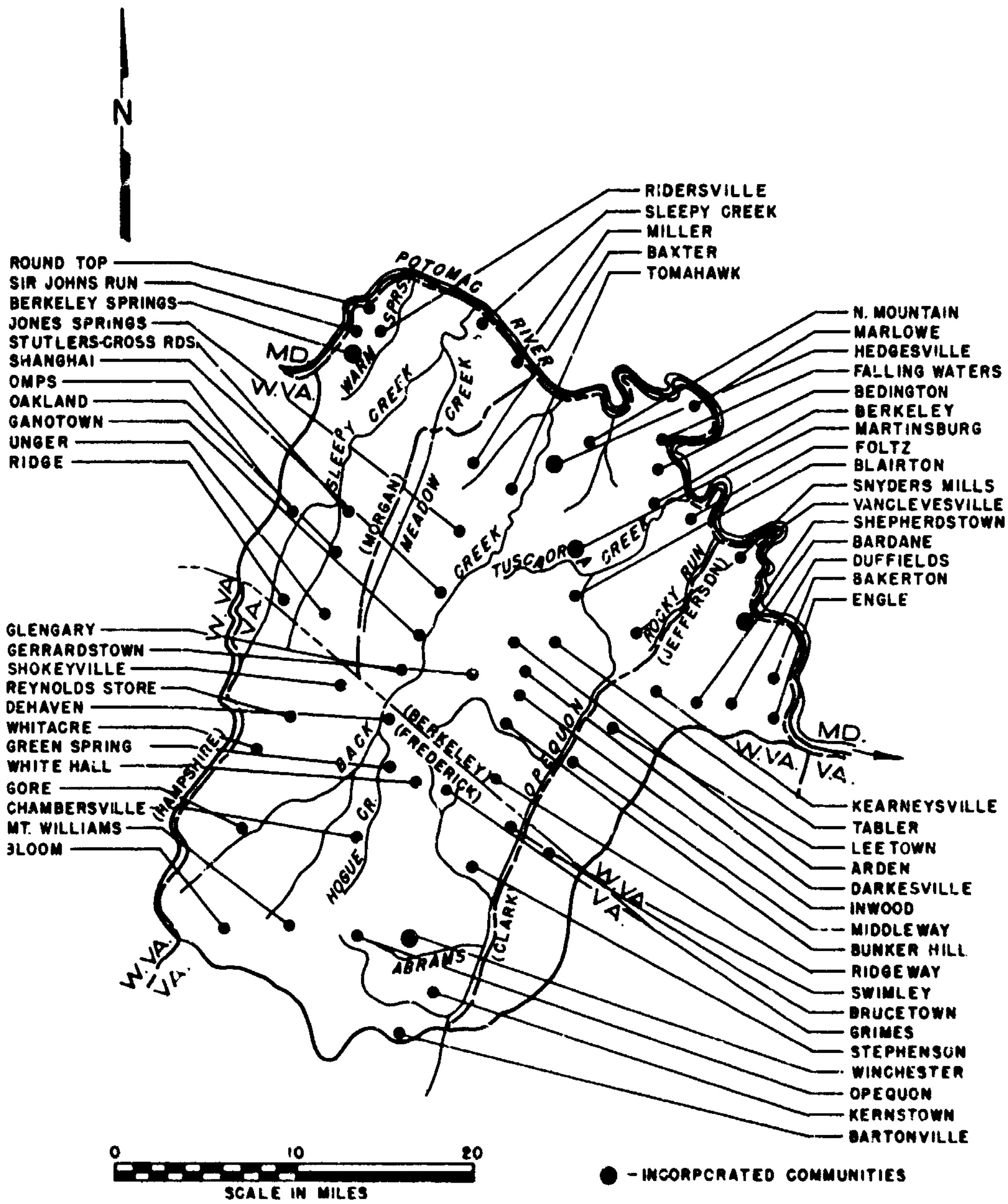
WATER SUPPLY REQUIREMENTS

Urban populations and associated rural residential populations projected for water use centers located within proximity or downstream from major reservoirs are shown in Table 65. The projected average and maximum daily municipal - district water supply requirements obtained by applying per capita daily rates shown in Table 66 to these area populations are given in Table 67.

The self-supplied industrial processing requirements shown for Subdivision 2 represent an annual increase of 6 per cent from 1960 uses based on Office of Business Economics employment projections for each of chemical and miscellaneous industries. Included also in this subdivision are requirements for food processing industries for which employment projections indicate annual increases of 5 per cent from 1960 water uses.

Self-supplied industrial processing requirements shown for Subdivisions 3 and 4 represent annual increases from 1960 uses of 5 per cent for food processing and miscellaneous uses, and 5 per cent for chemical processing, respectively. Cooling water requirements shown in Table 67 are based on estimated cooling needs associated with industrial processes.

It can be seen by inspection of supply requirements relative to dependable stream flows shown in Table 67 where water storage benefits may or may not accrue. Dependable supplies to the Winchester, Virginia, area (Subdivision 1) are shown for the North Fork Shenandoah in the <u>Shenandoah River Basin Report</u>, dated April 1961.



POTOMAC SUB-BASIN AREA

SLEEPY, BACK AND OPEQUON BASINS
STATES, COUNTIES AND COMMUNITIES

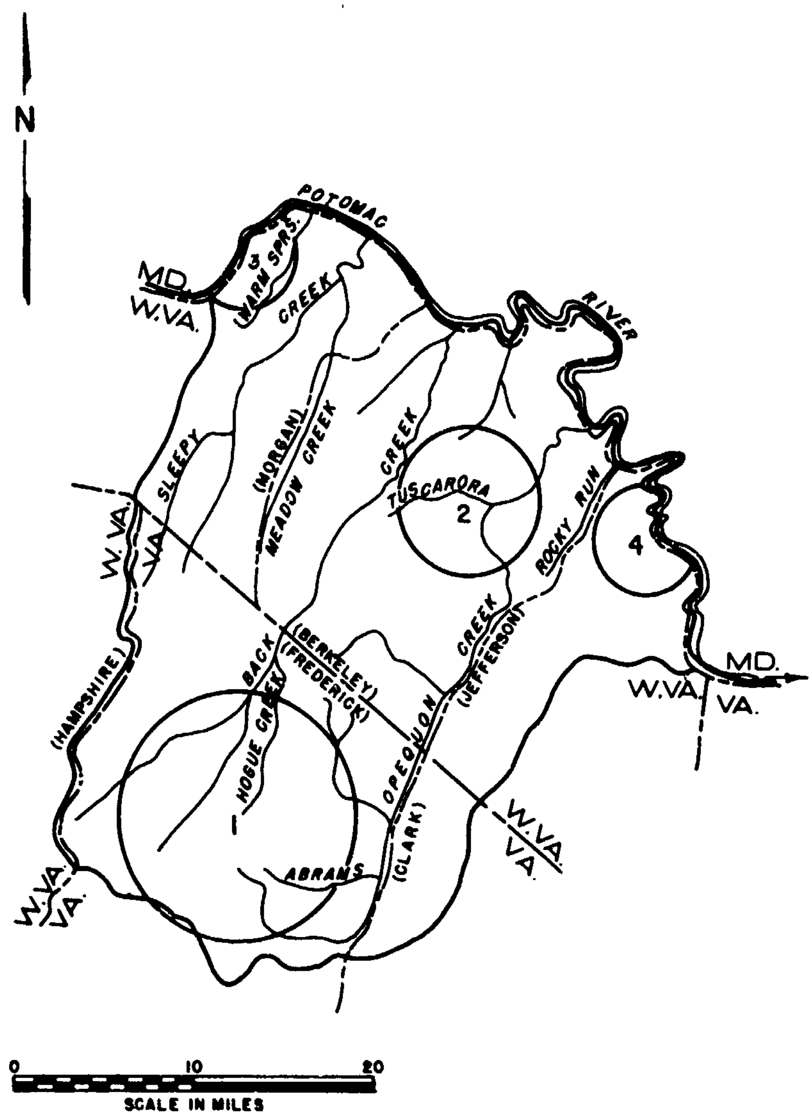
FIGURE 93

Table 63

Sleepy, Back, and Opequon Basins

Populations by Counties and Residence Categories

County and State	% in Basin	Total	Farm	Non-Farm Rural Residential	Non-Farm Small Town	Non-Farm Urban
			1960			
Frederick, Va.	90	33,210	4,770	13,050	1,350	14,040
Jefferson, W. Va.	50	9,300	1,750	3,400	800	3,350
Berkeley, W. Va.	100	33,900	4,100	10,800	600	18,400
Morgan, W. Va.	55	4,620	1,430	1,980	495	715
Totals		81,030	12,050	29,230	3,245	36,505
			1985			
Frederick, Va.	90	53,910	4,140	21,420	1,980	26,370
Jefferson, W. Va.	50	14,350	1,500	5,450	1,500	5,900
Berkeley, W. Va.	100	45,700	3,600	14,000	1,000	27,100
Morgan, W. Va.	55	5,170	1,210	2,475	495	990
Totals		119,130	10,450	43,345	4,975	60,360
			2010			
Frederick, Va.	90	88,010	3,690	29,700	3,320	51,300
Jefferson, W. Va.	50	20,500	1,250	7,500	2,000	9,750
Berkeley, W. Va.	100	62,600	3,300	17,900	1,700	39,700
Morgan, W. Va.	55	5,775	935	2,915	495	1,430
Totals		176,885	9,175	58,015	7,515	102,180



POTOMAC SUB-BASIN AREA
SLEEPY, BACK AND OPEQUON BASINS
DEVELOPMENT CENTERS

FIGURE 94

Table 64

Sleepy, Back, and Opequon Basins

Population Subdivisions

Subdivision Number	Location of Subdivision Sub-Basin	County	% County Population
Sub. No. 1	Upper Opequon & Back	Frederick, Va.	90
Sub. No. 2	Middle Opequon	Berkeley, W. Va.	100
Sub. No. 3	Potomac River	Morgan, W. Va.	55
Sub. No. 4	Potomac River	Jefferson, W. Va.	50

Table 65

Populations Served by Central Water Supply Systems
in Vicinity and Downstream of Major Reservoirs

Sub-Basin and Identifying Community	Subdivision Number	Subdivision Populations 1960	1985	2010
Upper Opequon & Back Creeks Winchester, Va.	1			
Rural Residential		6,000	10,710	22,300
Urban		14,040	26,370	51,300
Total		20,040	37,080	73,600
Middle Opequon Martinsburg, W. Va.	2			
Rural Residential		2,430	6,300	12,085
Urban		16,560	24,300	35,730
Total		18,990	30,600	47,815

Table 65 (Continued)

Populations Served by Central Water Supply Systems
in Vicinity and Downstream of Major Reservoirs

Sub-Basin and Identifying Community	Subdivision Number	Subdivision Populations 1960	1985	2010
Potomac River				
Berkeley Springs, W. Va.	3			
Rural Residential		495	1,240	2,185
Urban		715	990	1,430
Total		1,210	2,230	3,615
Potomac River				
Shepherdstown, W. Va.	4			
Rural Residential		850	2,725	5,625
Urban		3,350	5,900	9,750
Total		4,200	8,625	15,375

Table 66

Sleepy, Back, and Opequon Basins

Per Capita Daily Municipal - District Demand Rates

Sub-Basin and Identifying Community	Subdivision Number	Per Capita Daily Gallons 1960	1985	2010
Upper Opequon & Back				
Winchester, Va.	1			
Average		150	206	263
Maximum		225	281	338
Middle Opequon				
Martinsburg, W. Va.	2			
Average		133	183	233
Maximum		199	240	299
Potomac River				
Berkeley Springs, W. Va.	3			
Average		195	268	341
Maximum		292	365	438
Potomac River				
Shepherdstown, W. Va.	4			
Average		40	55	70
Maximum		60	75	90

Table 67

Sleepy, Back, and Opequon Basins

Municipal - District and Industrial Water Requirements
Relative to Dependable Surface Water Supply

Sub-Basin and Identifying Community	Subdivision Number	Million Gallons Per Day 1960	1985	2010
Upper Opequon & Back Creeks	1			
Winchester, Va.			(1)	
Middle Opequon	2			
Martinsburg, W. Va.				
Municipal - District				
Average		2.8	6.2	12.4
Maximum		4.2	8.1	15.8
Industrial Processing		3.3	6.0	8.7
Cooling		[1.5]	[3.3]	[5.0]
Totals				
Average		6.1	12.2	21.1
Maximum		7.5	14.1	24.5
Surface Supply		.6	.6	.6
Warm Springs Run	3			
Berkeley Springs, W. Va.				
Municipal - District				
Average		0.2	0.6	1.2
Maximum		0.3	0.8	1.6
Industrial Processing		0.3	0.7	1.1
Totals				
Average		0.5	1.3	2.3
Maximum		0.6	1.5	2.7
Surface Supply		0	0	0
Potomac River	4			
Shepherdstown, W. Va.				
Municipal - District				
Average		0.2	0.5	1.1
Maximum		0.3	0.7	1.4
Industrial Processing		0.9	2.0	3.2
Totals				
Average		1.1	2.5	4.3
Maximum		1.2	2.7	4.6
Surface Supply		196	196	196

(1) Water obtained from North Fork Shenandoah River.

QUALITY CONTROL REQUIREMENTS

In Table 68 are shown the projected waste loads and design loads for the stream and waste receiving flows required to maintain quality objectives in stream reaches downstream from major reservoirs. The waste loads or P.E.'s of BOD_5 shown in Table 68 constitute an estimate of residual materials contained in projected municipal and/or industrial treatment plant effluents received in local and upstream reaches. Design P.E.'s for the particular stream reaches represent associated stream assimilative capacities originating from computations involving deoxygenation and reaeration velocity constants obtained from stream sampling in these areas. Points at which samples were collected are shown in Figure 95, the data for which are appended to the December 1959 Potomac River Basin Study Report, corresponding to Stations: C-2, C-3, C-4, D-1, C-5, D-2, and C-6.

The requirements for quality control and design minimum 7-day, 10-year return flows shown in Table 69 may be compared for purposes of determining locations and amounts of increased stream flow required to meet objectives.

MAJOR RESERVOIRS - WATER SUPPLY AND QUALITY CONTROL

Discussions on water quality and sanitation relative to possible reservoir sites in the Potomac Basin are given on pages 61-64 of the December 1959 Potomac River Basin Study Report. The Back Creek site (Back Creek Site 3 and present Site 22) now under investigation is located in an area of good quality water.

The Opequon Creek site now under consideration (Opequon Creek Site 4 and present Site 7) is subject to excessive sewage bacterial pollution and oxygen consuming materials contained in treated municipal and industrial waste effluents from Winchester, Virginia. These pollutants would enter from Abrams Creek, approximately midway of the reservoir.

Because of the particular location of incoming wastes to the reservoir, only certain areas could be recommended as a source of municipal water supply. The area of the reservoir upstream or south of Abrams Creek embayment would be limited as a raw water source depending upon the extent to which Abrams Creek water diffused upstream. The reservoir area downstream from Abrams Creek would not be suitable as a source of water because of aesthetics involved and nutrient fertilization of filter-obstructing, taste and odor producing algae. Similarly, area restrictions in recreational use of the reservoir for the protection of health would be required. The reservoir could be used for all purposes if the treated sewage from Winchester was diverted to a point below the dam.

The City of Winchester, Virginia, and adjacent industries would be the most immediate potential users of water from this reservoir.

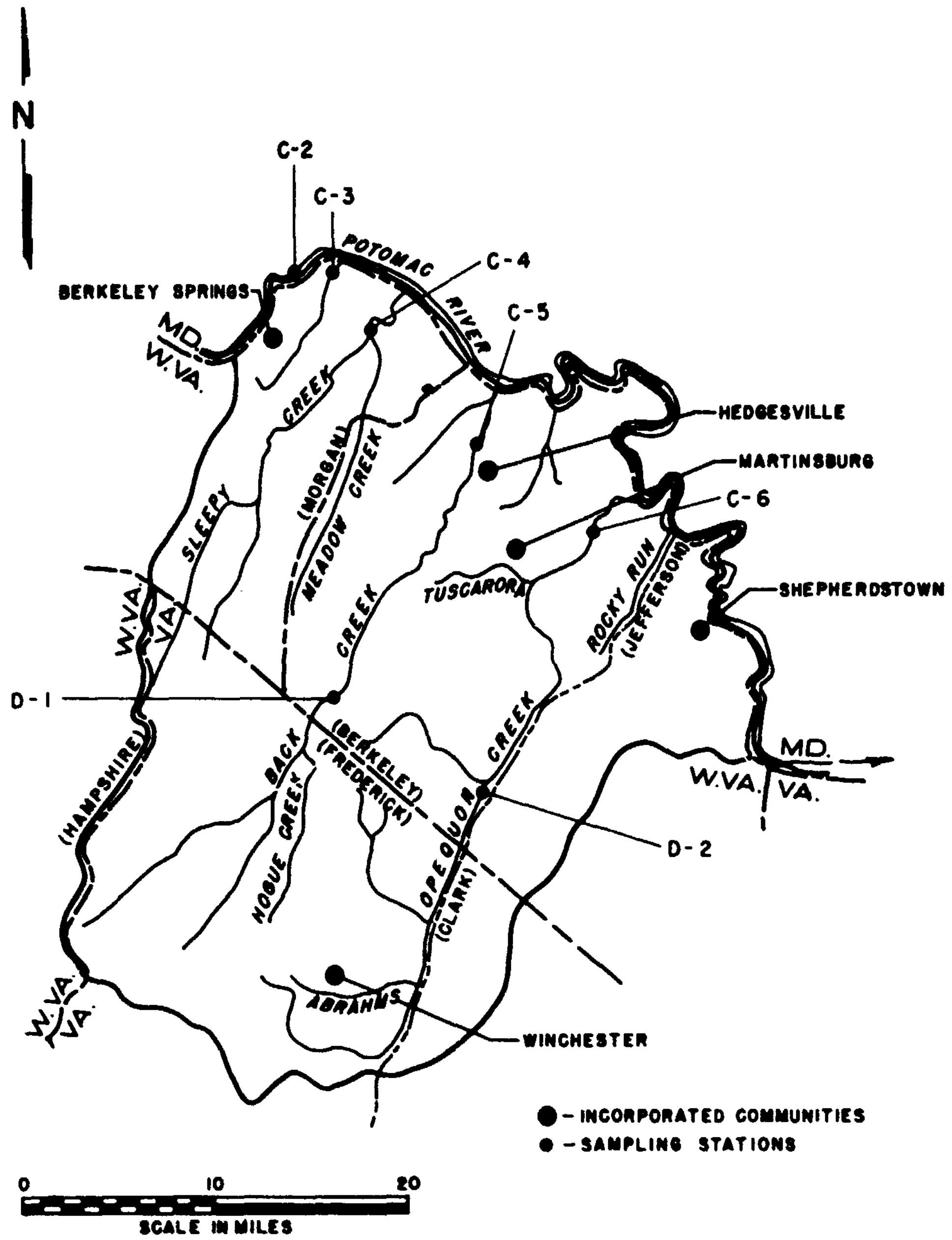
Table 68

Sleepy, Back, and Opequon Basins

Flow Requirement for Pollution Abatement
D.O. Objective - 5 ppm at 26°C

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
Opequon Creek Winchester Reach (1)	1			
P.E. Received		4,000	5,900	8,700
Design P.E. per cfs		130	130	130
cfs Required		31	45	67
7-day, 10-year cfs		0	0	0
Back Creek Dehaven, W. Va.	1a			
P.E. Received		1,000	1,500	2,150
Design P.E. per cfs		130	130	130
cfs Required		7.5	11.5	16.5
7-day, 10-year cfs		3	3	3
Opequon Creek Martinsburg Reach	2			
P.E. Received		4,725	6,120	7,110
Upstream Residual		1,800	2,650	4,000
Total Received		6,525	8,770	11,110
Design P.E. per cfs		98	98	98
cfs Required		67	90	113
7-day, 10-year cfs		3	3	3
Warm Springs Run Berkeley Springs Reach	3			
P.E. Received				
Municipal		300	450	540
Industrial		900	1,235	1,575
Total Received		1,200	1,685	2,115
Design P.E. per cfs		162	162	162
cfs Required		7.4	10.5	13
7-day, 10-year cfs		0	0	0
Potomac River Shepherdstown Reach	4	(See Conococheague and Antietam Creek Sections)		

(1) Assumes wastes discharged downstream from major reservoir.



POTOMAC SUB-TRIBUTARIES

SLEEPY, BACK AND OPEQUON CREEKS
SAMPLING STATION LOCATIONS
PHS SURVEY 1958

FIGURE 95

Table 69

Sleepy, Back, and Opequon Basins

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water,	1960-cfs		1985-cfs		2010-cfs		Design Min.	
and Waste Source	W.S.	Q.C.	W.S.	Q.C.	W.S.	Q.C.	W.S.	Q.C.
Opequon Creek								
Winchester, Va.		31		45		67	0	0
Municipal	N. Fk. Shen.		N. Fk. Shen.		N. Fk. Shen.			
Total Required		31		45		67		
Increase Required		31		45		67		

Remarks - storage benefits; Winchester waste effluent to be piped below dam. Diversion from North Fork Shenandoah returned in Opequon Creek as effluent (adjustement for losses) to be used as part of flow requirement for quality control at Martinsburg.

Stream, Water, and Waste Source	1960 W.S.	1960 Q.C.	1985 W.S.	1985 Q.C.	2010 W.S.	2010 Q.C.	Design Min. W.S.	Design Min. Q.C.
Back Creek								
Dehaven, W. Va.	Ground	7.5	Winchester	11.5	Winchester	16.5	1	3
Total Required		7.5		11.5		16.5		
Increase Required		4.5		8.5		13.5		

Remarks - storage benefits; Dehaven identifies general area of waste discharge only.

Stream, Water, and Waste Source	1960 W.S.	1960 Q.C.	1985 W.S.	1985 Q.C.	2010 W.S.	2010 Q.C.	Design Min. W.S.	Design Min. Q.C.
Opequon Creek								
Martinsburg, W. Va.		67		90		113	1	3
Municipal								
Average	4.3		9.6		19.1			
Maximum	6.5		12.5		25.0			
Industrial	5.1		9.3		13.4			
Totals								
Average		76.4		108.9		145.5		
Maximum		78.6		111.8		151.4		
Total Required		78.6		111.8		151.4		
Increase Required		75.6		108.8		148.4		

Remarks - storage benefits; quality satisfactory for water supply and quality control. Diversion from North Fork Shenandoah as effluent (adjusted for losses) from Winchester to be used as part of flow requirement for quality control.

Table 69 (Continued)

Sleepy, Back, and Opequon Basins

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Warm Springs Run								
Berkeley Springs, W. Va.		7.4		10.5		13	0	0
Municipal								
Average	0.3		1.0		1.9			
Maximum	0.5		1.3		2.5			
Industrial	0.5		1.1		1.7			
Total								
Average		8.2		12.7		16.6		
Maximum		8.4		12.9		17.2		
Total Required		8.4		12.9		17.2		
Increase Required		8.9		12.9		17.2		

Remarks - storage benefits; without sufficient storage, water supply taken from Potomac River and waste effluent piped to Potomac River showing no benefit.

Two sources of water, however, are available to these users, viz., the North Fork Shenandoah River, presently in use, and a spring once used but now abandoned. These sources offer sufficient water to meet demands for the foreseeable future.

The water released from the reservoir, after having undergone natural purification and conditioning in the open stream, could be used as a raw water source downstream. The City of Martinsburg, West Virginia, and the Berkeley County Public Service District could each benefit from an assured low flow increase in Opequon Creek. Abandoned quarries and springs are presently being used by these water consumers. Although the hardness of the water (285 ppm hardness) is about 200 ppm greater than usually recommended for finished water, there would be no advantage in using Opequon Creek as a source since the hardness of Opequon Creek water is of the same magnitude.

In the event that water demands in the Berkeley County and Martinsburg area exceed present supplies, two alternate sources are available, viz., the Potomac River and linkage with the Winchester, Virginia, supply. This site offers potential pollution abatement benefits by low flow augmentation at and below the dam.

Assured increases in low flows from Opequon Creek would improve the quality of Potomac River water and benefit the water supply at Washington, D. C.

To determine whether or not stored water could be utilized and therefore be assigned a benefit for water supply and pollution abatement purposes, the requirements where waters are removed and returned as waste are added together and compared with recorded minimum or statistical design minimum flows. Table 69 shows the total requirements with design minimum flows included as a means of determining needs for the utilization of stored water.

A supplemental rep devoted to benefit analyses will include detailed studies on storage benefits in this and all downstream study areas.

CATOCTIN CREEK (MD.) AND MONOCACY RIVER BASINS

DESCRIPTION OF AREA AND MAJOR RESERVOIRS

The Monocacy and Catoctin Basins comprise a portion of the Piedmont area located in Maryland and Pennsylvania. The Catoctin Creek watershed is entirely within the State of Maryland, occupying an area of 121 square miles in the southwestern section of Frederick County. The area drained by the Monocacy River in Frederick and Carroll Counties, Maryland, is 742 square miles, and in Adams County, Pennsylvania, about 228 square miles for a total of 970 square miles. The Monocacy River Basin is the fourth largest sub-basin of the Potomac, exceeded in size by the Shenandoah, South Branch Potomac, and North Branch Potomac River Basins.

Catoctin Creek enters the Potomac River downstream from Brunswick, Maryland, 162 river miles upstream from the mouth of the Potomac at Chesapeake Bay and about 52 river miles above Washington, D. C. The Monocacy River enters the Potomac River downstream from Point of Rocks, Maryland, a distance of 153.5 river miles from the mouth of the Potomac at Chesapeake Bay and about 43.5 river miles above Washington, D. C.

From the upper to lower elevations, these basins are oriented lengthwise in a southwesterly position. Catoctin Basin extends northeasterly from the Potomac River about 35 river miles and the Monocacy Basin about 75 river miles (see Figure 96).

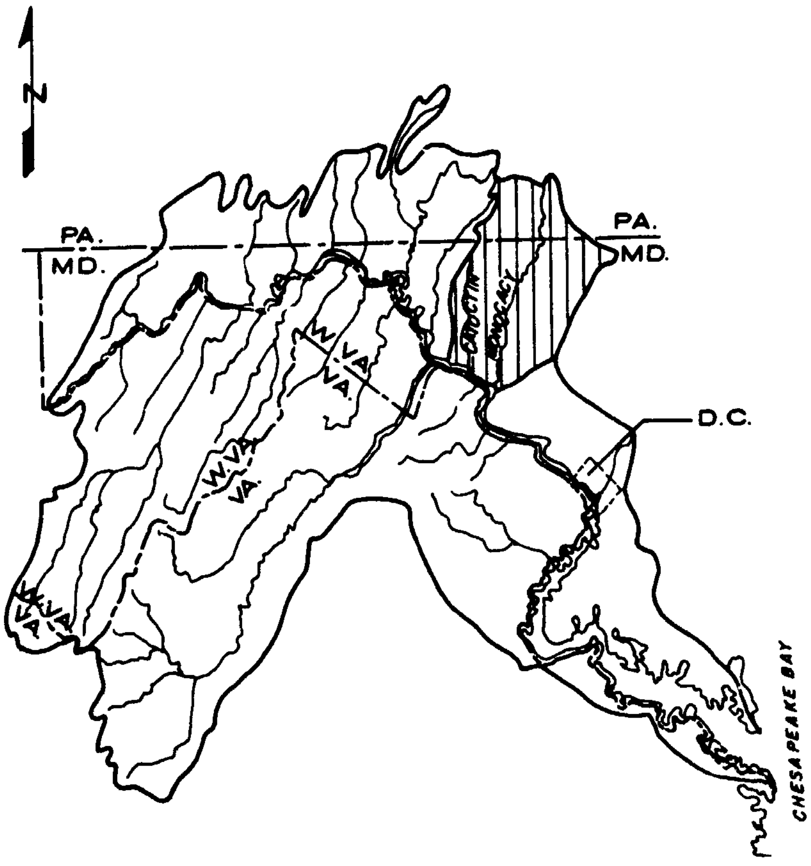
Catoctin Creek rises near Wolfsville, Maryland, and the Monocacy River is formed at the confluence of Marsh and Rock Creeks in the vicinity of the boundary line between Maryland and Pennsylvania.

The major watershed areas of Catoctin Creek and the Monocacy River are characterized by rolling hills, woods and cultivated land. During rainy periods considerable amounts of silt and other runoff material are carried in the stream waters to the Potomac River.

For 29 years (1929-1958) of stream gaging at Jug Bridge, near Frederick, Maryland (drainage area - 817 square miles), the average flow of the Monocacy River has been 920 cubic feet per second (cfs) with extremes of 51,000 cfs and 35 cfs. For 11 years of stream gaging (1947-1958) near Middletown, Maryland (drainage area - 66.9 square miles), the average flow of Catoctin Creek has been 79.7 cfs with extremes of 7,760 cfs and 1.3 cfs.

There is one reservoir under consideration for this area and the backwaters of a proposed Main Stem Potomac reservoir extend into the Monocacy Basin (see Figure 97). The proposed site on the Monocacy River at Six Bridge, Maryland, is partially in Carroll and Frederick Counties, and lies approximately 2 miles west of Keysville, Maryland. The drainage area at this site is 308 square miles and the valley width is 2,000 feet. The conservation pool would be at an elevation of 175 feet with a maximum water surface elevation of 383 feet. The reservoir would be about 12 miles long and cover 3,500 acres.

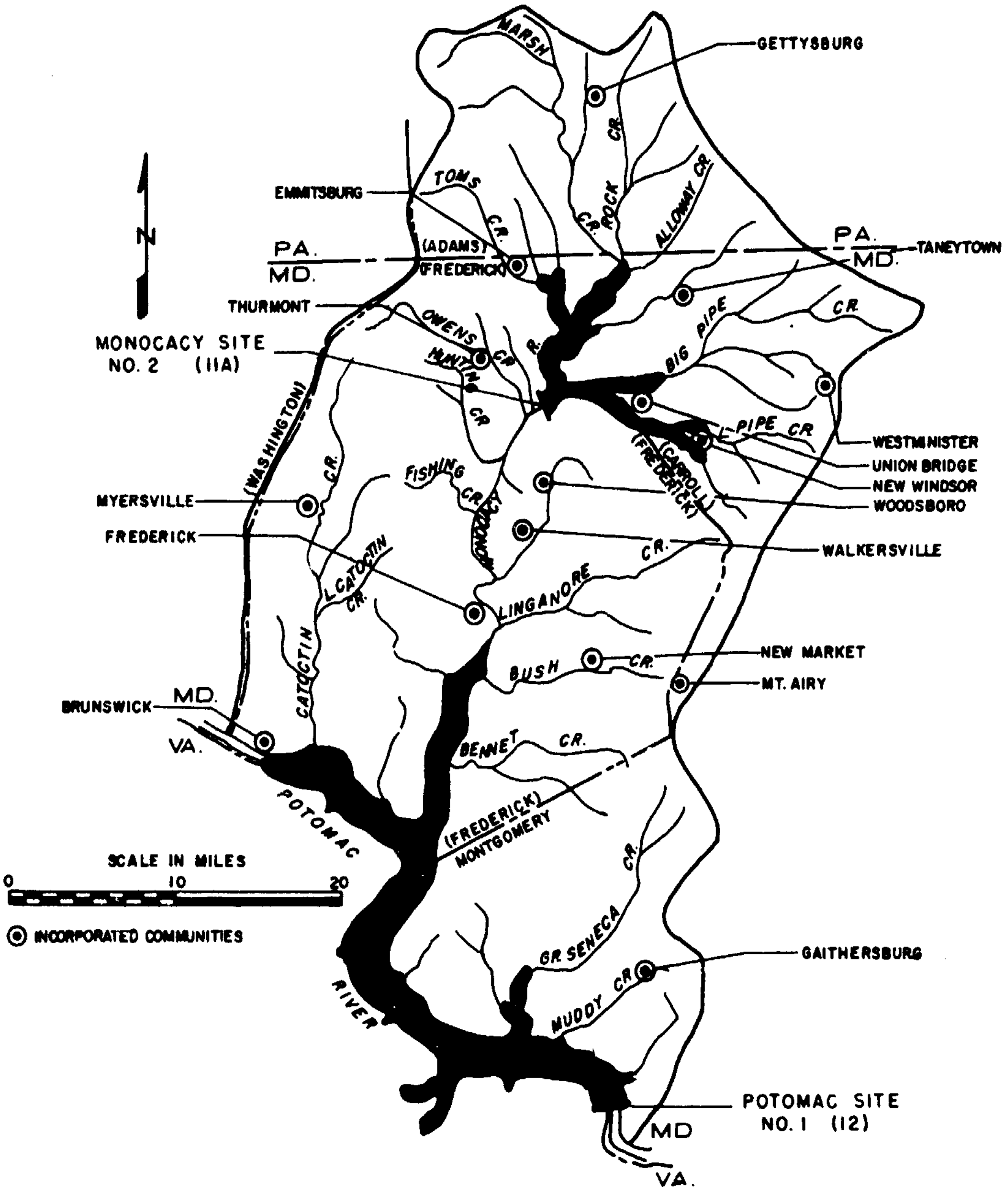
The Main Stem Potomac River reservoir is described in the section dealing with Catoctin Creek, Goose Creek, and Broad Run Basins in Virginia.



POTOMAC DRAINAGE AREA

SUB-BASIN STUDY REGION
CATOCTIN CREEK AND MONOCACY RIVER

FIGURE 96



POTOMAC SUB-TRIBUTARIES

CATOCTIN CREEK AND MONOCACY RIVER
PROPOSED RESERVOIR SITES

FIGURE 97

PRESENTATION OF DATA

POPULATIONS - PRESENT AND FUTURE

At the present time, approximately 122,000 persons reside in the Monocacy River and Catoctin Creek Basins, constituting about one-seventh of the Upper Potomac Basin populations. About 47,200 persons or 38 per cent of all persons residing in these basin areas are located in urban or incorporated communities (see Figure 98). About 91 per cent of the urban population in the two basins reside in the Monocacy River Basin.

It is estimated that populations in the Monocacy and Catoctin Basin area, by the years 1985 and 2010, will be 191,000 and 283,000, respectively (see Table 70). Urban populations by the years 1985 and 2010 will have increased to 84,000 and 145,000, respectively.

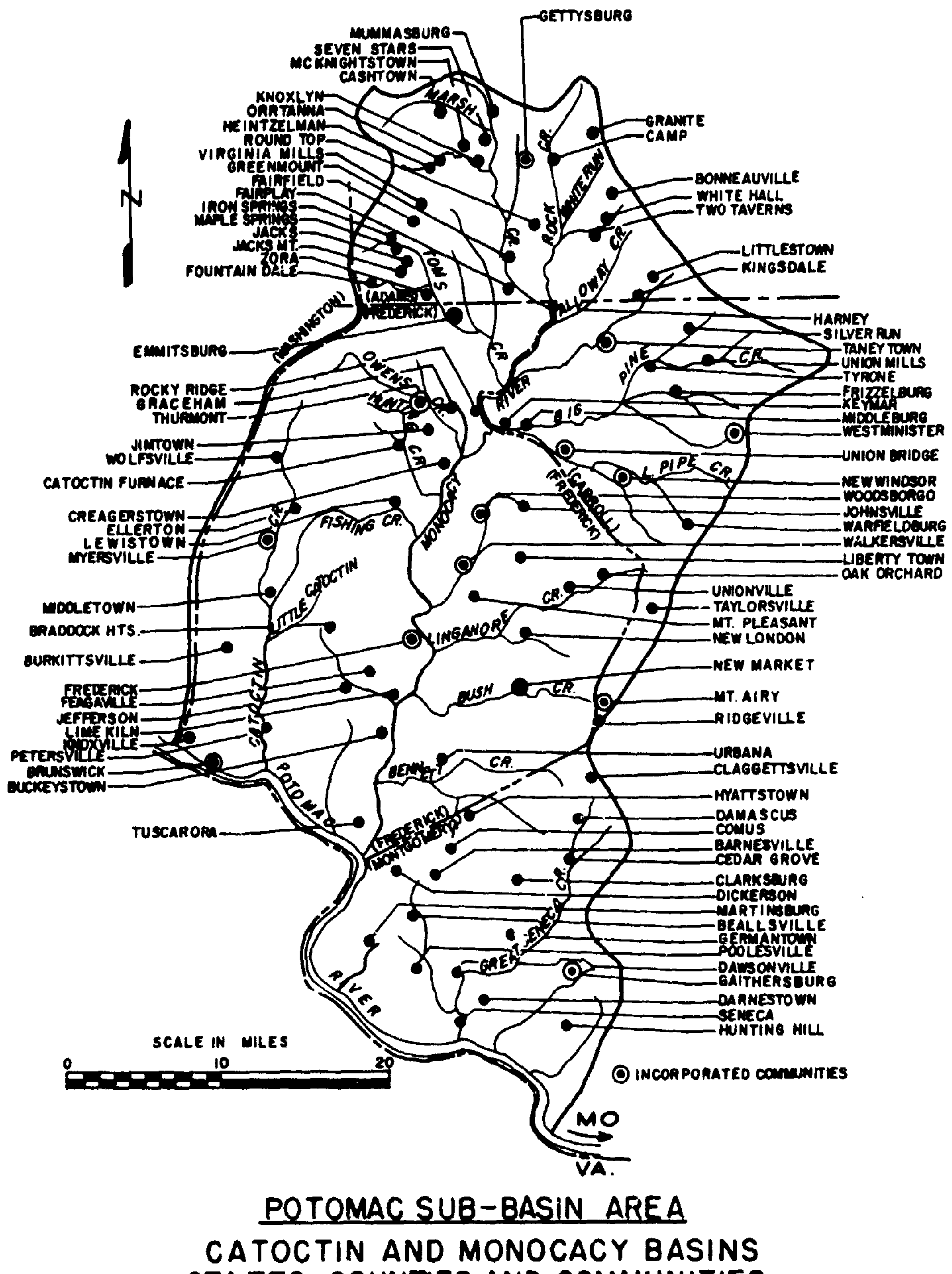
The locations of major population centers for which projected water supply and waste source information is desired are shown in Figure 99. Table 71 shows the percentage breakdown of urban county populations expected to form the nucleus of these development centers. The portion of Montgomery County, Maryland, shown in Figure 99 is not included in this study region since it is considered as part of Metropolitan Washington, D. C., and is dealt with in a separate evaluation of that area.

WATER SUPPLY REQUIREMENTS

Urban populations and associated rural residential populations projected for water use centers located within proximity or downstream from major reservoirs are shown in Table 72. The projected average and maximum daily municipal - district water supply requirements obtained by applying per capita daily rates shown in Table 73 to these populations are given Table 74. The cooling water requirements shown for the Main Stem Potomac are based on power requirements relative to this area and areas downstream.

QUALITY CONTROL REQUIREMENTS

In Table 75 are shown the projected waste loads and design loads for the stream and waste receiving flows required to maintain quality objectives in stream reaches downstream from major reservoirs. The waste loads or P.E.'s of BOD_5 shown in Table 75 constitute an estimate of residual materials contained in projected municipal and/or industrial treatment plant effluents received in local and upstream reaches. Design P.E.'s for the particular stream reaches represent associated stream assimilative capacities originating from computations involving deoxygenation and reaeration velocity constants obtained from stream sampling in these areas. Points at which samples were collected are shown in Figure 100, the data for which are appended to the December 1959 Potomac River Basin Study Report, corresponding to Stations: F-7, F-6, F-5, F-4, F-1, D-7, D-6, D-5, and D-4.



POTOMAC SUB-BASIN AREA

CATOCTIN AND MONOCACY BASINS
STATES, COUNTIES AND COMMUNITIES

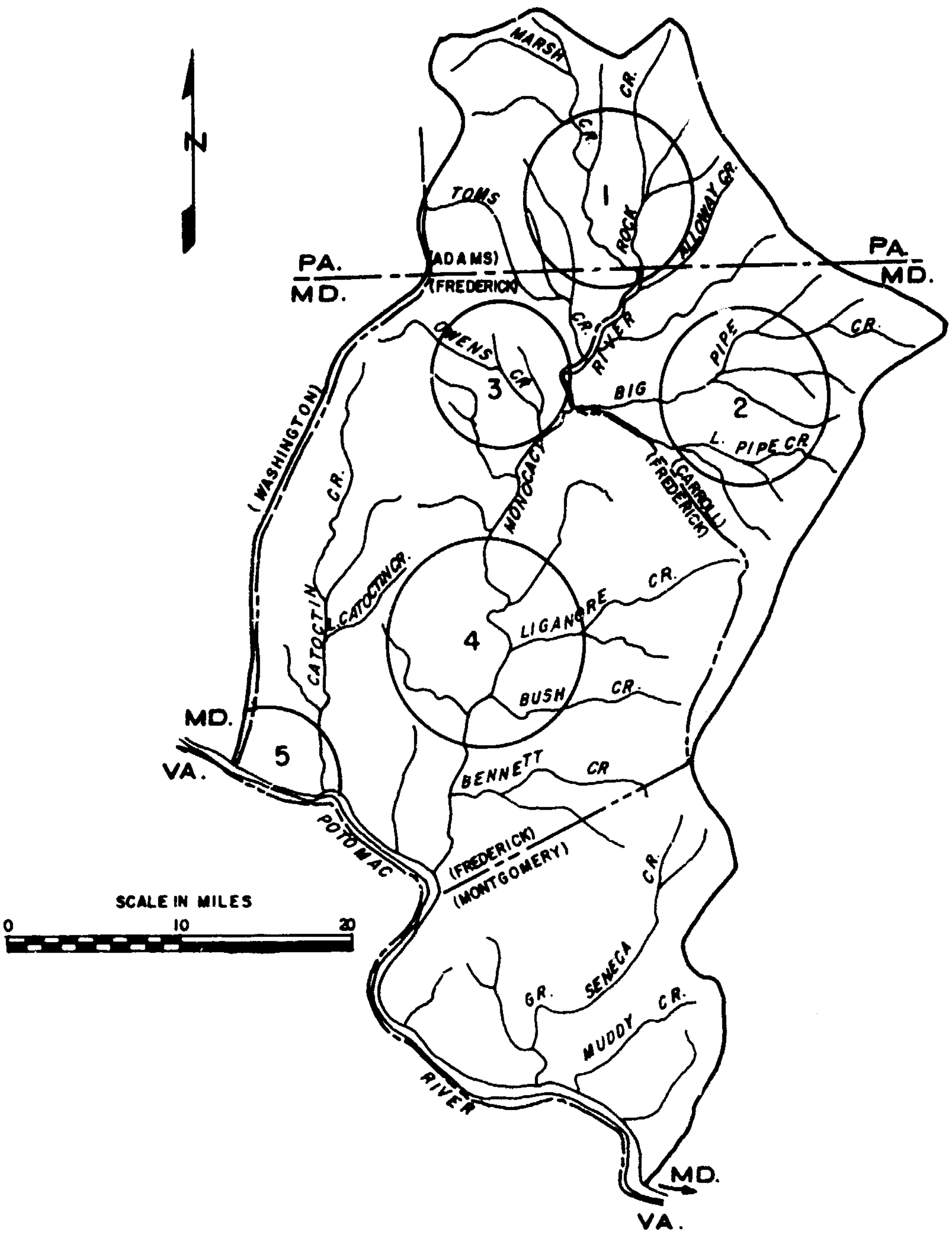
FIGURE 98

Table 70

Catoctin Creek (Md.) and Monocacy River Basins

Populations by Counties and Residence Categories

County and State	% in Basin	Total	Farm	Non-Farm: Rural Residential	Non-Farm: Small Town	Non-Farm: Urban
			1960			
Adams, Pa.	48	24,855	4,700	8,300	2,400	9,455
Frederick, Md.	100	72,000	10,600	25,000	4,200	32,200
Carroll, Md.	48	25,300	4,850	12,480	2,450	5,520
Totals		122,155	20,150	45,780	9,050	47,175
			1985			
Adams, Pa.	48	38,690	4,130	13,775	3,935	16,850
Frederick, Md.	100	109,300	7,900	39,700	6,000	55,700
Carroll, Md.	48	43,195	3,550	24,720	3,790	11,135
Totals		191,185	15,580	78,195	13,725	83,685
			2010			
Adams, Pa.	48	59,950	2,350	21,650	8,495	27,455
Frederick, Md.	100	159,500	5,700	46,300	7,700	99,800
Carroll, Md.	48	63,645	2,590	36,770	6,095	18,190
Totals		283,095	10,640	104,720	22,290	145,445



POTOMAC SUB-BASIN AREA

CATOCTIN AND MONOCACY BASINS
DEVELOPMENT CENTERS

FIGURE 99

Table 71

Catoctin Creek (Md.) and Monocacy River Basins

Population Subdivisions

Sub-Basin and County	% County Population	Subdivision Numbers
Monocacy, Rock Creek Adams, Pa.	48	1
Monocacy, Double Pipe Creek Carroll, Md.	48	2
Monocacy, Owens Creek Frederick, Md.	15	3
Monocacy River Frederick, Md.	70	4
Potomac River Frederick, Md.	15	5

Table 72

Catoctin Creek (Md.) and Monocacy River Basins

Populations Served by Central Water Supply Systems
in Vicinity and Downstream of Major Reservoirs

Sub-Basin and Identifying Community	Subdivision Number	Subdivision Populations		
		1960	1985	2010
Middle Monocacy River Frederick, Md.	4			
Rural Residential		4,375	13,895	24,305
Urban		22,540	38,990	69,860
Total		26,915	52,885	94,165
Potomac River Brunswick-Knoxville, Md.	5			
Rural Residential		940	2,980	5,210
Urban		4,830	8,355	14,970
Total		5,770	11,335	20,180

Table 73

Per Capita Daily Municipal - District Demand Rates

Sub-Basin and Identifying Community	Subdivision Number	Per Capita Daily Gallons 1960	1985	2010
Monocacy River				
Frederick, Md.	4			
Average		139	191	243
Maximum		209	261	313
Potomac River				
Brunswick-Knoxville, Md.	5			
Average		114	157	200
Maximum		171	214	257

Table 74

Catoctin Creek (Md.) and Monocacy River Basins

Municipal Water Supply Requirements Relative to Dependable Surface Water Supply

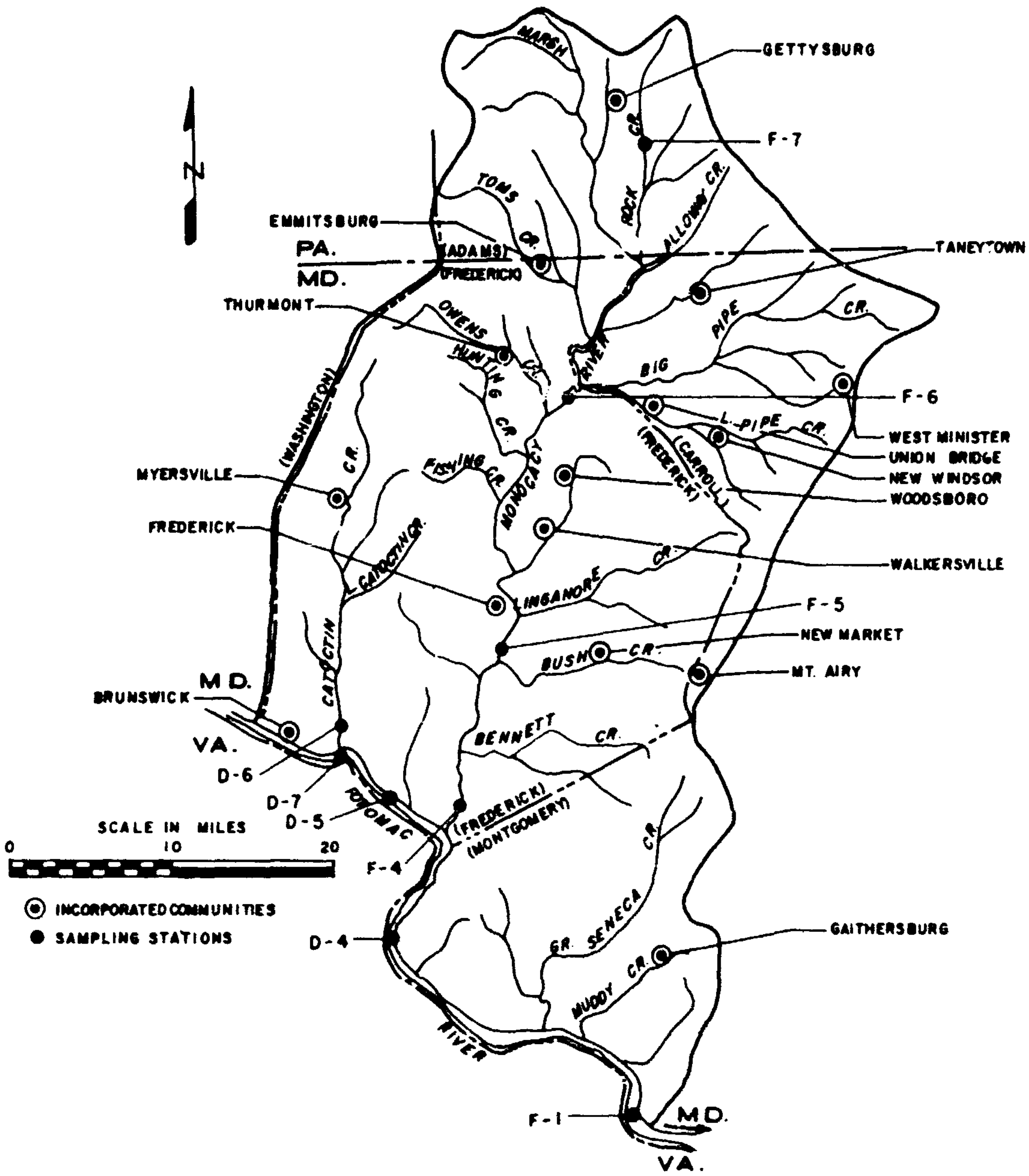
Sub-Basin and Identifying Community	Subdivision Number	Million Gallons Per Day 1960	1985	2010
Monocacy River				
Frederick, Md.	4			
Municipal - District				
Average		4.0	10.8	24.0
Maximum		5.9	14.5	30.6
Surface Supply		21	21	21
Potomac River				
Brunswick-Knoxville, Md.	5			
Municipal - District				
Average		0.7	1.8	4.0
Maximum		1.0	2.5	5.0
Surface Supply		420	420	420
Potomac River				
Dickerson, Md.	5b			
Cooling		(340)	(680)	(1,020)
Surface Supply		460	460	460

Table 75

Catoctin Creek (Md.) and Monocacy River Basins

Flow Requirements for Pollution Abatement
D.O. Objective - 5 ppm at 26°C

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
Monocacy River				
Frederick Reach	4			
Upstream Residual		4,175	7,470	10,520
P.E. Received		6,720	10,600	14,100
Total Received		10,895	18,070	24,620
Design P.E. per cfs		135	135	135
cfs Required		81	134	182
7-day, 10-year cfs		52	52	52
Potomac River				
Dickerson Reach	5b			
P.E. Received		2,820	5,180	8,500
Upstream Residual		21,800	33,300	42,800
Tributary Residual		31,365	46,205	58,440
Total Received		55,985	84,685	109,740
Design P.E. per cfs		140	140	140
cfs Required		400	603	785
7-day, 10-year cfs		1,000	1,000	1,000



POTOMAC SUB-TRIBUTARIES

CATOCTIN CREEK AND MONOCACY RIVER
SAMPLING STATION LOCATIONS
PHS SURVEY 1958

FIGURE 100

The requirements for quality control and design minimum 7-day, 10-year return flows shown in Table 75 may be compared for purposes of determining locations and amounts of increased stream flow required to meet objectives.

MAJOR RESERVOIRS - WATER SUPPLY AND QUALITY CONTROL

Discussions on water quality and sanitation relative to possible reservoir sites in the Potomac Basin are given on pages 61-64 of the December 1959 Potomac River Basin Study Report.

The reservoir now under consideration on the Monocacy River (Site 11A) is subject to residual upstream contamination by municipal and industrial wastes. Stream sampling results show that the reservoir would receive BOD_5 equivalent to unstabilized BOD_5 from a population of about 15,000 persons and would receive sewage bacteria in numbers greater than usually recommended for raw water supplies requiring complete conventional water supply treatment.

The reservoir in providing stabilization or treatment of residual wastes and runoff material entering from upstream would suffer dissolved oxygen losses in deeper water areas; and nutrient stabilization by-products would promote conditions favoring nuisance weeds and accumulations of filter-obstructing and taste and odor producing algae in surface and shallow areas. It could be expected, however, that water existing at certain levels in the immediate vicinity of the dam after being stabilized within the reservoir would be suitable as a source of supply. With further conditioning in the open stream, waters released from the reservoir would be suitable for supply at downstream locations including Frederick, Maryland. This situation could be alleviated by development of headwater reservoirs to make additional water available.

To determine whether or not stored water could be utilized and therefore be assigned a benefit for water supply and pollution abatement purposes, the requirements where waters are removed and returned as waste are added together and compared with recorded minimum or statistical design minimum flows. Table 76 shows the total requirements with design minimum flows included as a means of determining needs for the utilization of stored water.

Effects and possible benefits relative to the backwaters of the main stem reservoir are dealt with in connection with downstream conditions and needs. A supplemental report devoted to benefit analyses will include detailed studies on storage benefits in this and all downstream study regions.

Table 76

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Monocacy River								
Frederick, Md.		81		134		182	32	52
Municipal								
Average	6.2		16.6		37			
Maximum	9.1		22.3		47			
Totals								
Average	87.2		150.6		219			
Maximum	90.1		156.3		229			
Total Required	90.1		156.3		229			
Increase Required*	38.1		104.3		177			
Remarks - storage benefits.								
Potomac River								
Dickerson, Md.		400		603		785	703	1,000
Cooling	[525]		[1,050]		[1,575]			
Total Required	400		603		785			
Remarks - storage benefits possible; incidential cooling benefit.								

*Consumptive losses in upper basin water use areas would significantly reduce minimum flows, and the increase required would be greater than that shown for 1985 and 2010.

CATOCTIN (VA.), GOOSE CREEK, AND BROAD RUN BASINS

DESCRIPTION OF AREA AND MAJOR RESERVOIRS

The Catoctin Creek, Goose Creek, and Broad Run Basins comprise a portion of the Piedmont area located in Virginia. The total watershed area included in these sub-basins is about 600 square miles, most of which is located in Loudoun County (520 square miles), with the remainder in Fauquier County.

Catoctin Creek, Goose Creek, and Broad Run enter the Potomac River from the south at river mileages above Washington, D. C., of 50, 32, and 29 miles, respectively.

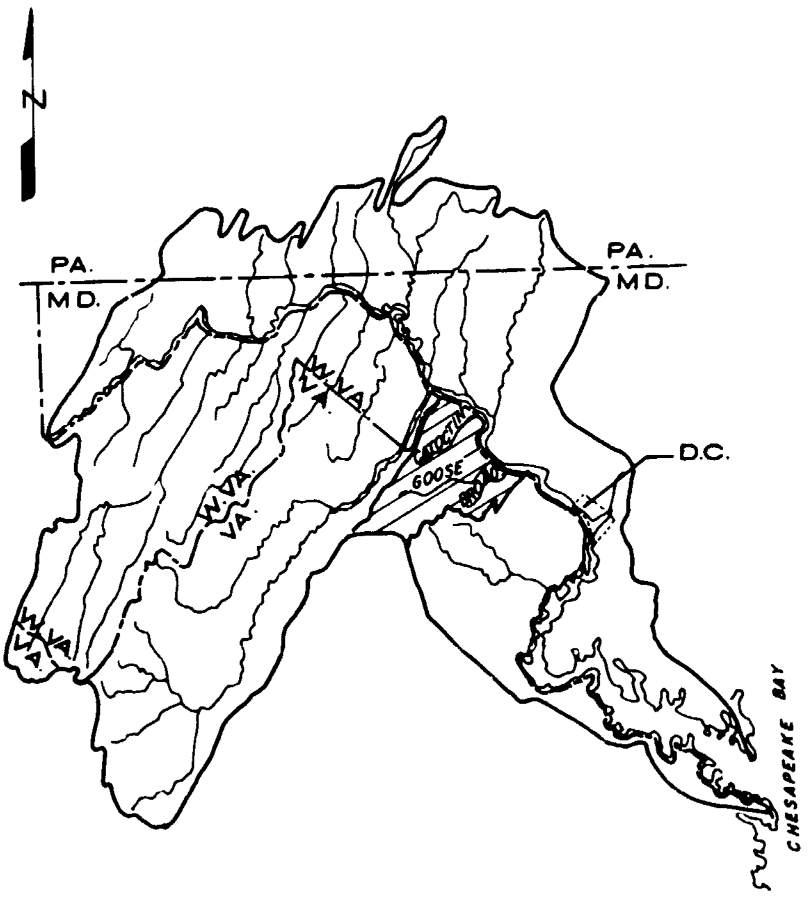
From the upper to lower elevations, these basins are oriented lengthwise in a northeasterly position. Catoctin Creek Basin extends southwesterly from the Potomac River about 51 miles; Goose Creek Basin (385 square miles) extends about 32 miles; and Broad Run Basin extends about 13 miles (see Figure 101).

Catoctin Creek rises in the Blue Ridge Mountains at the western boundary of Loudoun County about 5 miles north of Round Hill, Virginia, and flows northeasterly to the Potomac. Goose Creek rises in the Blue Ridge Mountains near Linden, Virginia, in Fauquier County and flows a winding northeasterly course to the Potomac near Leesburg, Virginia, about 16 miles above Great Falls.

Broad Run rises at the southern border of Loudoun County near Lenah, Virginia, and flows a northeasterly course to the Potomac about 13 miles upstream from Great Falls. The watershed areas are characterized by mountainous terrain in the upper extremities to rolling hills and open valleys in the lower areas.

For 31 years (1909-1912 and 1930-1958) of stream gaging near Leesburg, Virginia (drainage area - 338 square miles), the average flow of Goose Creek has been 305 cubic feet per second (cfs) with extremes of 45,000 cfs and 0.4 cfs. Official stream gages do not exist on Catoctin Creek and Broad Run.

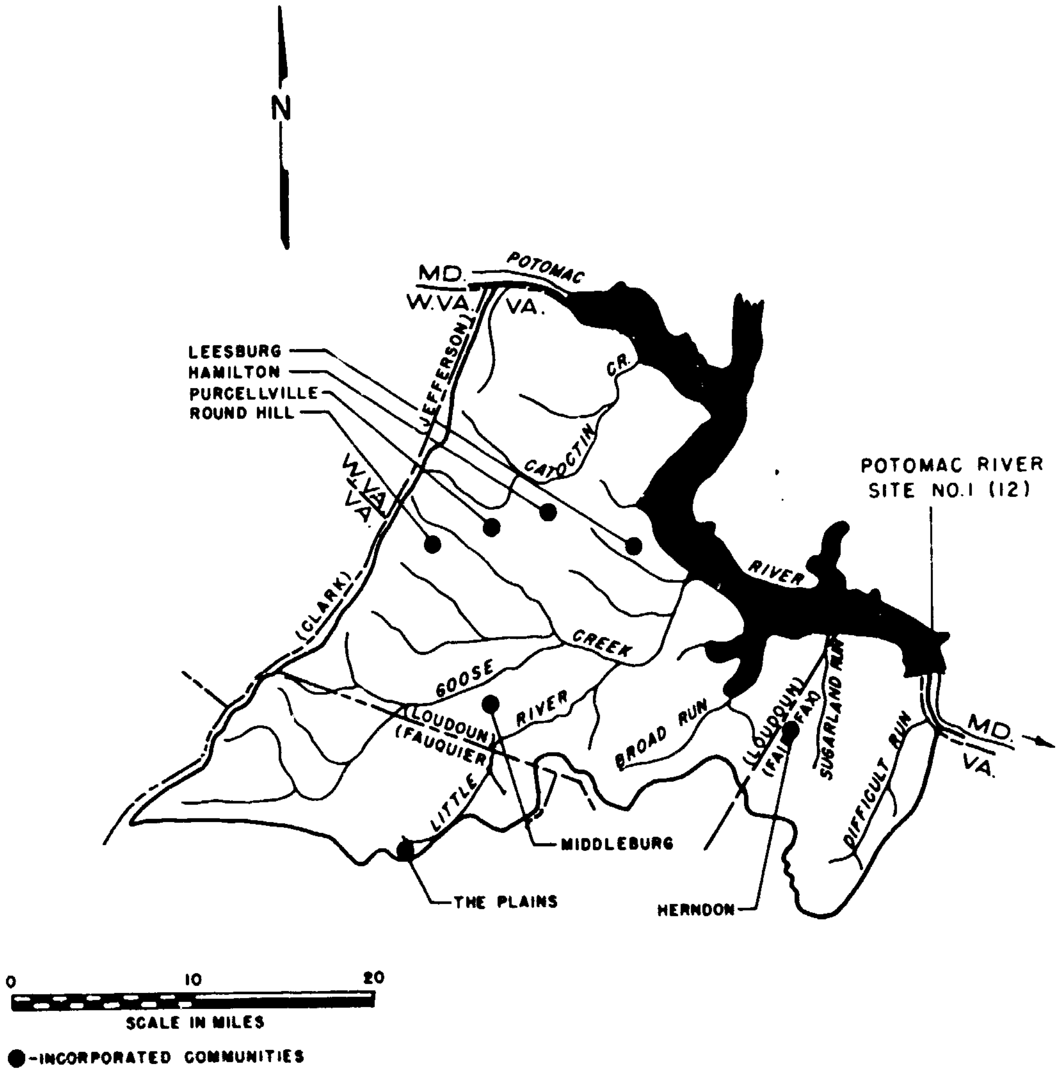
The Catoctin, Goose, and Broad Run Basin areas lie adjacent to a possible reservoir site considered for the Main Stem of the Potomac River (see Figure 102). The dam site is located at the upstream end of Minnehaha Island, approximately 2 miles upstream of the Great Falls of the Potomac River. The drainage area at the site is 11,457 square miles and the valley width is 2,750 feet. The elevation of the conservation pool would be 226 feet with a maximum water surface elevation of 247 feet. The maximum water surface elevation is limited to this elevation by the extensive railroad yards at Brunswick, Maryland. The reservoir would be about 39.7 miles long and would cover about 27,500 acres of mostly open farm land. Several small communities lie in the reservoir area.



POTOMAC DRAINAGE AREA

SUB-BASIN STUDY REGION
CATOCTIN CREEK, GOOSE CREEK AND BROAD RUN

FIGURE 101



POTOMAC SUB-TRIBUTARIES

CATOCTIN CREEK, GOOSE CREEK AND BROAD RUN
PROPOSED RESERVOIR SITE

FIGURE 102

An alternate site to the River Bend Dam first mentioned is located on the Potomac River, 6.5 miles upstream from Great Falls. The drainage area is 11,400 square miles and the valley width is about 2,700 feet. The elevation of the conservation pool would be 226 feet, with a maximum water surface elevation of 247 feet. The reservoir would be 35.7 miles long and cover 22,700 acres.

PRESENTATION OF DATA

POPULATIONS - PRESENT AND FUTURE

At the present time, approximately 24,000 persons reside in the Catoctin Creek, Goose Creek, and Broad Run area, constituting about one-fortieth of the Upper Potomac Basin populations. About 3,300 persons or 14 per cent of all persons residing in these basin areas are located in urban or incorporated communities (see Figure 103). About 76 per cent of the urban population in the three basins reside in the Goose Creek area.

It is estimated that by the years 1985 and 2010, the populations in these three basins will be 32,700 and 43,600, respectively (see Table 77). Urban populations by the years 1985 and 2010 will have increased to 8,000 and 20,000, respectively.

The locations of major population centers for which projected water supply and waste source information is desired are shown in Figure 104. Table 78 shows the percentage breakdown of urban county populations expected to form the nucleus of these development centers.

WATER SUPPLY REQUIREMENTS

Urban populations and associated rural residential populations projected for water use centers located within proximity of the major reservoir on the Main Stem Potomac are shown in Table 79. The projected average and maximum daily municipal - district water supply requirements obtained by applying per capita daily rates shown in Table 80 to these area populations are given in Table 81. It can also be seen by an inspection of supply requirements relative to the dependable stream flows shown in Table 81 where water storage benefits may or may not accrue.

QUALITY CONTROL REQUIREMENTS

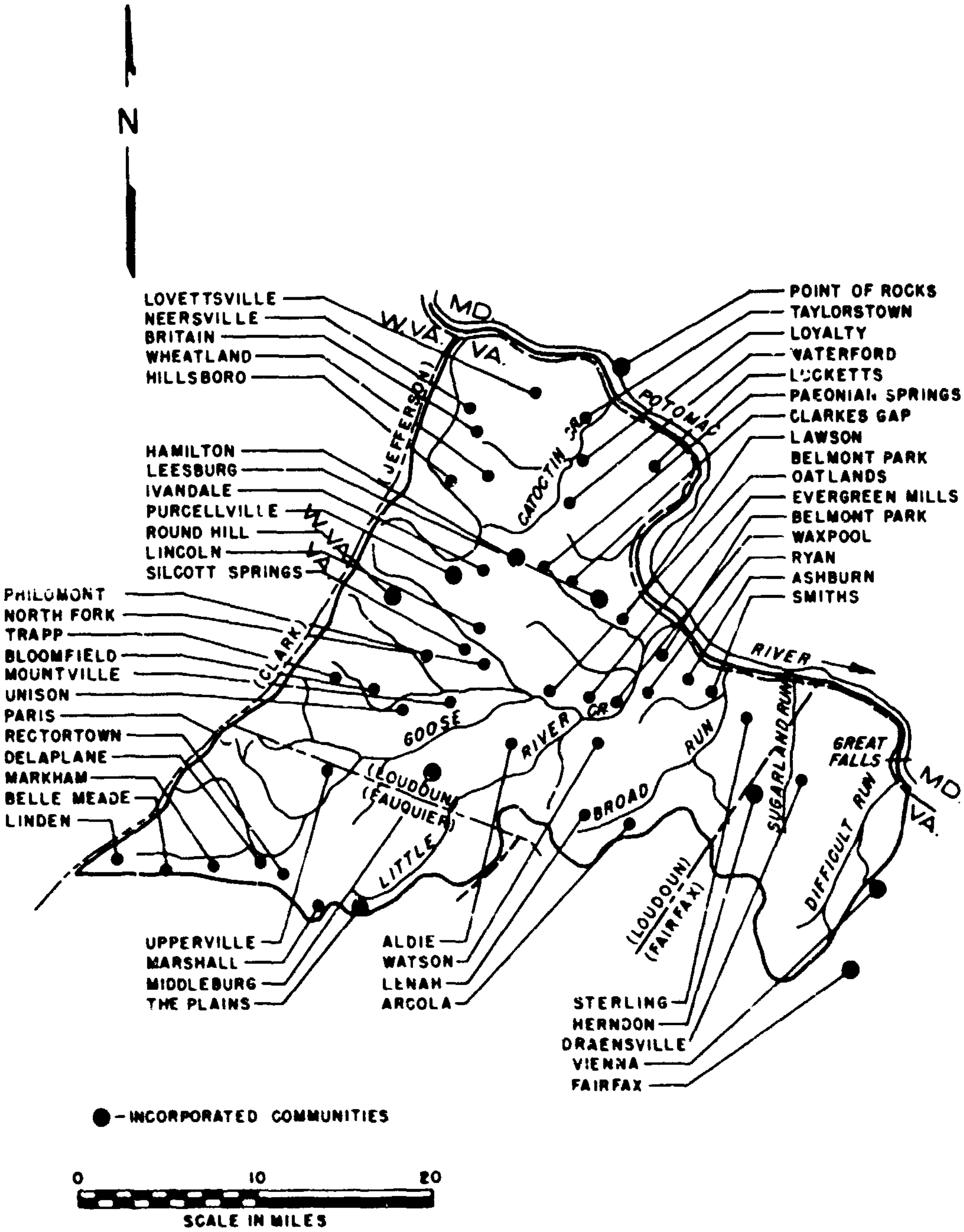
In Table 82 are shown the projected waste loads and design loads for the stream and waste receiving flows required to maintain quality objectives in stream reaches receiving wastes. The waste loads or P.E.'s of BOD_5 shown in Table 82 constitute estimates of residual materials contained in projected municipal treatment plant

effluents. Design P.E.'s for the particular stream reaches represent associated stream assimilative capacities originating from computations involving deoxygenation and reaeration velocity constants as obtained from stream sampling in these areas. Points at which samples were collected are shown in Figure 105, the data for which are appended to the December 1959 Potomac River Basin Study Report, corresponding to Stations D-4 and F-1.

The requirements for quality control and design minimum 7-day, 10-year return flows shown in Table 82 may be compared for purposes of determining locations and amounts of increased stream flow required to meet objectives.

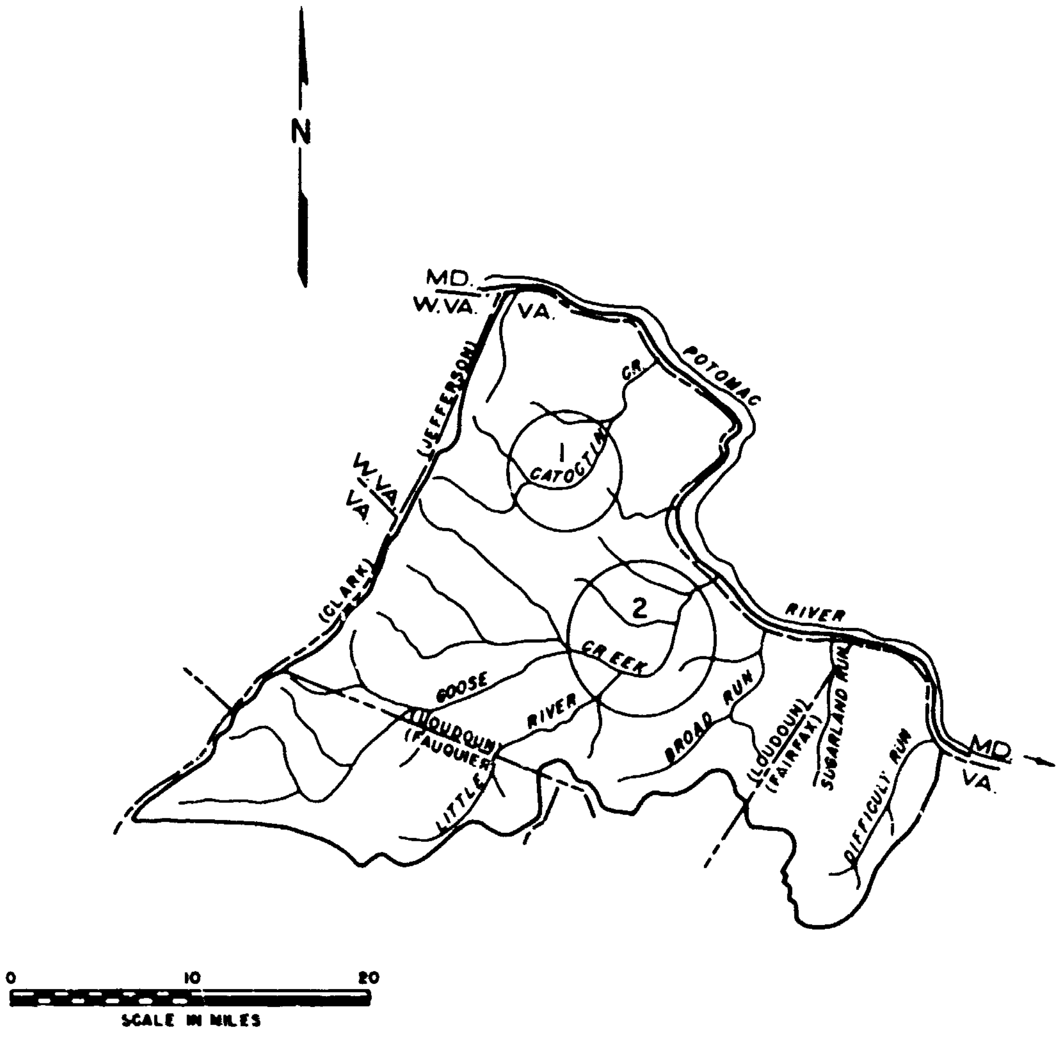
MAJOR RESERVOIRS - WATER SUPPLY AND QUALITY CONTROL

A discussion on water quality and sanitation relative to possible reservoir sites in the Potomac Basin is given on pages 61-64 of the December 1959 Potomac River Basin Study Report.



POTOMAC SUB-BASIN AREA
CATOCTIN, GOOSE AND BROAD RUN BASINS
STATES, COUNTIES AND COMMUNITIES

FIGURE 103



POTOMAC SUB-BASIN AREAS

CATOCTIN, GOOSE AND BROAD RUN BASINS
DEVELOPMENT CENTERS

FIGURE 104

Table 77

Catoctin Creek, Goose Creek, and Broad Run Basins
Populations by Counties and Residence Categories

County and State	% in Basin	Total	Farm	Non-Farm Residential	Non-Farm Small Town	Non-Farm Urban
			1960			
Loudoun, Va.	100	24,200	8,000	8,900	4,000	3,300
			1985			
Loudoun, Va.	100	32,700	6,000	13,500	5,300	7,900
			2010			
Loudoun, Va.	100	43,600	4,000	15,700	4,000	19,900

Table 78

Population Subdivisions

Sub-Basin and County	% County Population	Subdivision Numbers
Catoctin Creek		
Loudoun, Va.	23.5	1
Goose Creek		
Loudoun, Va.	76.5	2

Table 79

Catoctin Creek, Goose Creek, and Broad Run Basins

Populations Served by Central Water Supply Systems
in Vicinity and Downstream of Major Reservoirs

Sub-Basin and Identifying Community	Subdivision Number	Subdivision Populations 1960	1985	2010
Catoctin Creek Purcellville-Hamilton, Va.	1			
Rural Residential		525	1,600	2,700
Urban		775	1,850	4,700
Total		1,300	3,450	7,400
Goose Creek Leesburg, Va.	2			
Rural Residential		1,700	5,150	9,000
Urban		2,525	6,050	15,200
Total		4,225	11,200	24,200

Table 80

Per Capita Daily Municipal - District Demand Rates

Sub-Basin and Identifying Community	Subdivision Number	Per Capita Daily Gallons 1960	1985	2010
Catoctin Creek Purcellville-Hamilton, Va.	1			
Average		119	164	208
Maximum		179	224	268
Goose Creek Leesburg, Va.	2			
Average		119	164	208
Maximum		179	224	268

Table 81

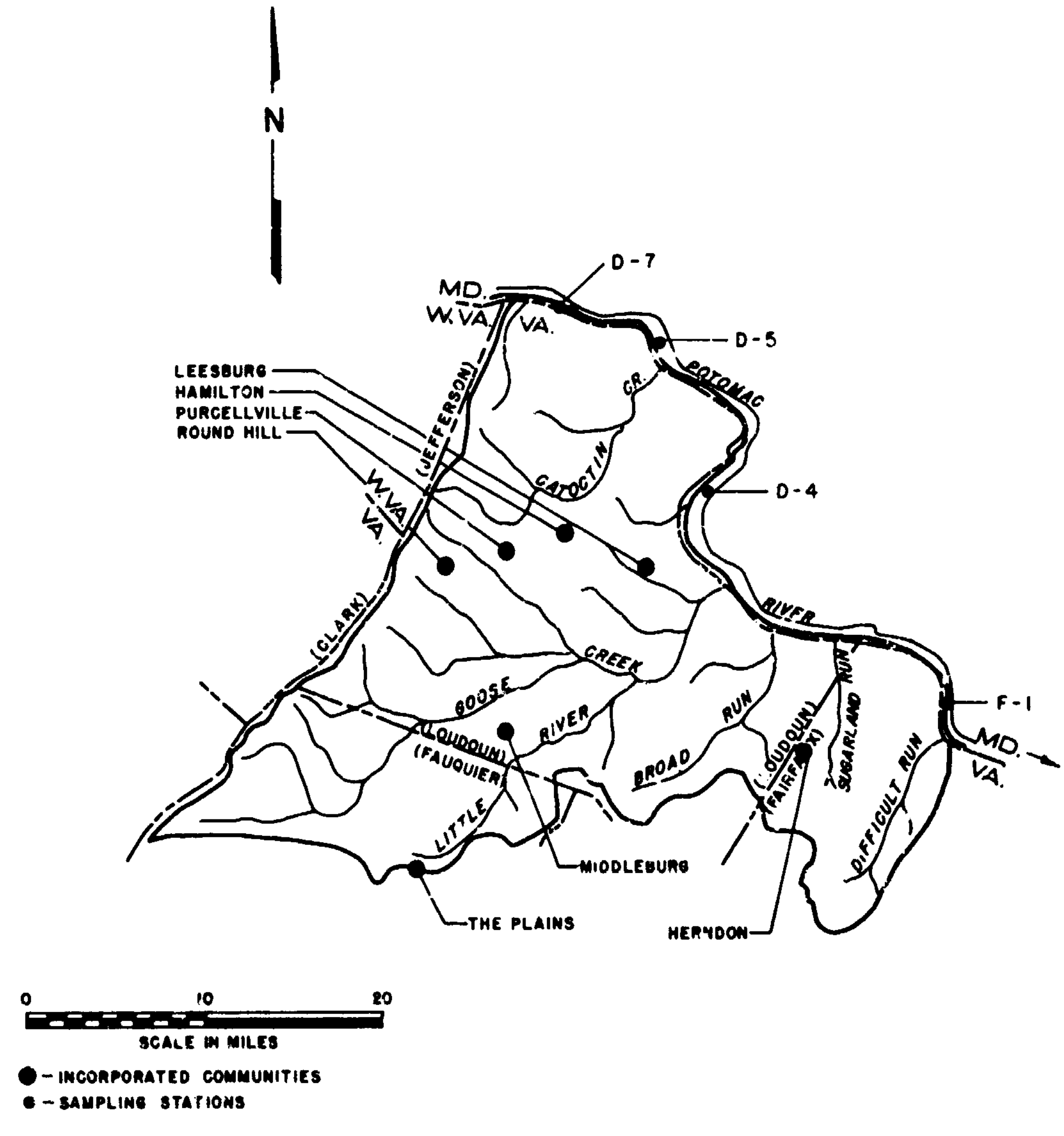
Municipal Water Supply Requirements Relative to Dependable Surface Water Supply

Sub-Basin and Identifying Community	Subdivision Number	Million Gallons Per Day		
		1960	1985	2010
Catoctin Creek	1			
Purcellville-Hamilton, Va.				
Municipal - District				
Average		0.2	0.6	1.6
Maximum		0.3	0.8	2.0
Surface Supply		0	0	0
Goose Creek	2			
Leesburg, Va.				
Municipal - District				
Average		0.5	1.8	5.0
Maximum		0.8	2.5	6.5
Surface Supply			0	0

Table 82

Flow Requirement for Pollution Abatement
D.O. Objective - 5 ppm at 26°C

Stream Name and Waste Receiving Reach	Subdivision Number	1960	1985	2010
Catoctin Creek	1			
Purcellville-Hamilton Reach				
P.E. Received		325	690	1,100
Design P.E. per cfs		135	135	135
cfs Required		2.4	5.1	8.1
7-day, 10-year cfs		0	0	0
Goose Creek	2			
Leesburg Reach				
P.E. Received		1,050	2,250	3,650
Design P.E. per cfs		135	135	135
cfs Required		7.8	16.7	27.0
7-day, 10-year cfs		2.0	2.0	2.0



POTOMAC SUB-TRIBUTARIES

CATOCTIN CREEK, GOOSE CREEK AND BROAD RUN
SAMPLING STATION LOCATIONS
PHS SURVEY 1958

FIGURE 105

Potomac River waters in this reach contain residual waste materials from approximately 350,000 persons and 45 water using industries. These waste materials, depending upon properties, concentrations, and time of stream travel from the point of discharge to this reach, exist in varied stages of biochemical degradation, chemical combination, physical separation, biological utilization, and bacterial die-off.

Stream sampling results show that during times of relatively low sustained stream flow (1,500-2,500 cfs), BOD_5 in waters entering this reach can be as high as 300,000 P.E. and will average approximately 150,000 P.E. per day. Samplings during times of highly variable flow (6,500-24,000 cfs) show that additional BOD_5 loads, presumably from high flushing and agricultural and natural runoff to the river, result in a combined daily average BOD_5 load to this reach equivalent to a population of more than one-half million persons.

Without upstream storage for quality control a variety of effects can exist within the extremes of these conditions. For example, samples collected at times of flash flows revealed numbers of coliform organisms in excess of maximum numbers recommended for raw water supplies requiring complete conventional treatment. The high turbidity associated with this condition appeared to reduce the solubility of oxygen and prevent dissolved oxygen recovery from nighttime losses by reducing sunlight penetration needed for normal photosynthetic oxygen production. Conversely, low flows and clear water provided conditions favoring the use of readily available nutrient materials by algal forms as evidenced by a greater utilization of carbon dioxide and resultant photosynthetic supersaturation of dissolved oxygen during these times.

The quality of water expected in the River Bend Reservoir over the next 50 years would be characterized as good for all uses, including water supply and recreational uses. The incoming water would be expected to have a high dissolved oxygen content, ranging from 5 to 14 parts per million (ppm); the biochemical oxygen demand should be low, i.e., less than one part per million, indicating a stabilized organic content; the pH on the alkaline side of neutral, ranging from 7.5 to 9.6; and the alkalinity should range from 21 to 107 ppm.

Storage would tend to improve the Potomac River water rather than degrade it. Bacteria would be markedly reduced in numbers, oxygen consuming substances would undergo greater stabilization, sediment would be reduced, radioactivity would be decreased, and inorganic matter would be evened out by the aging and averaging effect of storage. The only exception may be an increase in algae production because of greater opportunity for photosynthesis brought about as a result of clarification of the water and increased sunlight penetration. The algae are not viewed as a serious problem and can be controlled on the site if necessary.

Adequate continued protection of the quality of the water must be provided. The construction of the large Potomac River interceptor sewer to serve communities on both sides of the Potomac will prevent the entrance of sewage and industrial wastes into the Potomac River through the reservoir reach. Sanitary requirements for the anticipated development on the reservoir must be laid out and maintained rigidly. The water flowing into the reservoir from upstream must also continue to be protected.

The generally improved water quality and provision of water storage in this reservoir would be of great benefit to future water supplies at Frederick, Maryland; Frederick County, Maryland; Loudoun County, Virginia; and Metropolitan Washington, D. C. However, in view of the existence of several tributary sources of municipal and industrial wastes (viz., the Monocacy River entering approximately midway of the reservoir), care should be exercised in locating water intakes.

Part VII of the Potomac River Report, "Needs for Water Supply and Flow Regulation for Quality Control in the Washington Standard Metropolitan Area," will discuss further aspects of quality and flow in the River Bend Reservoir.

To assure that waters within the reservoir and those released would contain sufficient dissolved oxygen concentrations for protection of fish life within and downstream of the reservoir and provide sufficient supplemental waste assimilative capacity to the Potomac estuary, a means should be devised whereby mixing of bottom with surface water would be accomplished in the reservoir. Such a mechanism might consist of a submerged weir or diffusion device, so located and designed that "short-circuiting" of incoming water to the dam would be prevented. Additional assurance that released water would contain sufficient dissolved oxygen and a minimum of bottom decomposition products could be accomplished by withdrawing surface water by means of a series of multilevel outlets in the dam structure.

To determine whether or not stored water could be utilized and therefore be assigned a benefit for water supply and pollution abatement purposes, the requirements where waters are removed and returned as waste are added together and compared with recorded minimum or statistical design minimum flows. Table 83 shows the total requirements with design minimum flows included as a means of determining needs for the utilization of stored water.

A supplemental report devoted specifically to benefit analyses will include detailed studies on storage benefits in this and all downstream study areas.

Table 83

Daily Flow Requirements for Water Supply and Quality Control

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Catoctin Creek								
Purcellville-Hamilton, Virginia		2.4		5.1		8.1	0	0
Municipal								
Average	0.3		0.9		2.4			
Maximum	0.5		1.2		3.1			
Total								
Average		2.7		6.0		10.5		
Maximum		2.9		6.3		11.2		
Total Required		2.9		6.3		11.2		
Increase Required		2.9		6.3		11.2		

Remarks - storage benefits; if storage is not available, possible water supply from Potomac River.

Stream, Water, and Waste Source	1960-cfs W.S.	1960-cfs Q.C.	1985-cfs W.S.	1985-cfs Q.C.	2010-cfs W.S.	2010-cfs Q.C.	Design Min. W.S.	Design Min. Q.C.
Goose Creek								
Leesburg, Va.		7.8		16.7		27	0	2
Municipal								
Average	0.8		2.8		7.8			
Maximum	1.2		3.9		10.0			
Total								
Average		8.6		19.5		34.8		
Maximum		9.0		20.6		37.0		
Total Required		9.0		20.6		37.0		
Increase Required		8.5		20.1		36.5		

Remarks - storage benefits; if storage is not available, possible water supply from Potomac River.

DISCUSSION

The Water supply and pollution abatement requirements given in preceding sections of this report constitute estimates based on expansion of municipal and industrial enterprises existing in the Potomac Basin at the present time. Since it is entirely possible that new industries and types of product manufacture may develop in the basin, it is believed that these water requirement estimates may be somewhat conservative.

It should be pointed out that flow requirements to maintain the Interstate Commission Class "C" dissolved oxygen objective accomplishes a twofold effect, i.e., they protect the aquatic environment and associated self-purification elements in the stream and control concentrations or organic and inorganic materials associated with given amounts of biochemical oxygen demand.

Whereas 1-day, 30-year stream flows are used as the basis for establishing dependable surface supplies, it should be recognized that without water storage or low flow augmentation, withdrawals of stream flow for water supply that would seriously deplete the stream flow below this minimum should not be permitted. In some instances, therefore, benefit computations relating to storage projects should include credit for amounts of storage required to satisfy water supply requirements as well as credit for an additional amount required to maintain certain minimum flows in the stream. Where low flow augmentation would be provided for both water supply and pollution abatement, the pollution abatement flow as computed would satisfy the requirement for minimum flow to be maintained in the stream.

Benefit computations for areas where augmenting flow would be re-used for water supply and pollution abatement should take into account consumptive losses in upstream use areas. Such computations should also consider the effect of transbasin diversions which may significantly affect minimum flows of record.

It is noted in the foregoing sub-basin requirement analyses that certain water use areas other than those remotely located in relation to major projects have been omitted. Though located in the vicinity of a proposed impoundment area, these water users are omitted because of the possibility of waste interferences with water intake points. In some instances, it is noted that direct use could be made of the reservoir for water supply transporting wastes to a point below the dam. In such instances it is entirely possible that costs to transport these wastes would be chargeable to the project.

The benefit analyses to be submitted in a subsequent report will include consideration of all alternates available to meet requirements for water supply and pollution abatement in the absence of major storage projects.

PART VII

NEEDS FOR WATER SUPPLY AND FLOW REGULATION FOR QUALITY CONTROL IN THE WASHINGTON STANDARD METROPOLITAN AREA

ACKNOWLEDGMENTS

Successful completion of a study of this magnitude depends to a large extent upon the cooperation of responsible agencies in the area. The enthusiasm and cooperation obtained from the agencies in the Washington Metropolitan Area was of immeasurable aid in determining present and future water requirements.

The assistance provided in the conduct of the complex field investigation of the Potomac estuary in the Washington area deserves special recognition. Parking facilities and utilities for the trailer laboratory were provided at the Blue Plains Sewage Treatment Plant through the cooperation of Mr. Hugh Schreiber, Plant Superintendent. Arrangements for running determinations beyond the capacity of the trailer laboratory were made by Mr. David Auld, Director, District of Columbia Department of Sanitary Engineering, and his able assistant, Mr. Norman Jackson. A sample delivery service was also provided through the Department of Sanitary Engineering.

The facilities of the Corps of Engineers dock were made available as a base for sampling operations, and the boat basin at Bolling Field was made available by the U. S. Air Force for emergency docking.

The cooperation and assistance of all these agencies are gratefully acknowledged.

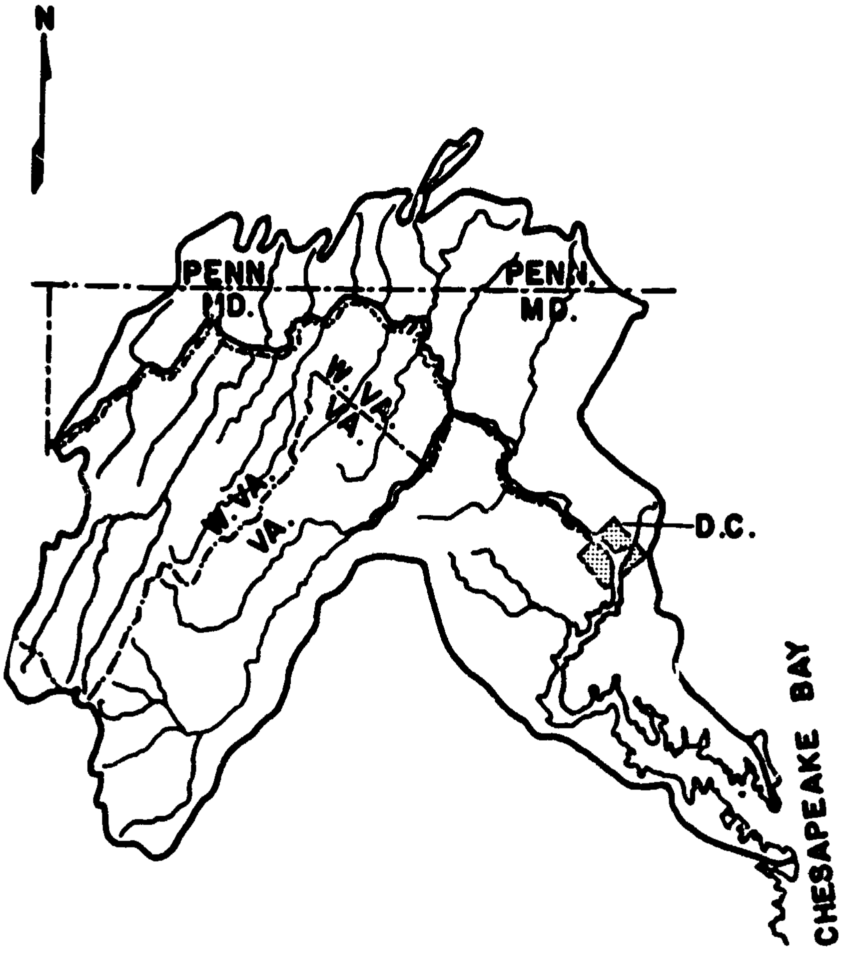
INTRODUCTION

Concern has been increasingly expressed regarding the adequacy of the uncontrolled Potomac River as a source of water supply and of water quality control flows for the needs of the Washington Standard Metropolitan Area (see Figure 106). As a part of the larger study with respect to the development of a comprehensive water resources plan for the Potomac River Basin, the needs concerning both quality and quantity aspects for water supply and water quality control flows for the Washington Metropolitan Area were prepared and are included within this part of the report.

To plan for the optimum development of available water resources, the future requirements must be estimated. Estimates for water supply and quality control flows were made for the years 1985 and 2010. Background information for the estimates consisted of an Economic Base Study by the U. S. Department of Commerce, Office of Business Economics, and engineering studies of the area by the U. S. Public Health Service. There is no certainty in forecasting future water demands for a fixed date, however, such estimates will be a certainty at some future time if population growth in the Metropolitan Area continues. Perhaps the estimated date of such demand may be in error.

This defect can be remedied by adjusting the scheduling of water resources development projects to meet the changed conditions.

The volume of water withdrawn for municipal water supply purposes becomes the volume of waste water produced, excepting a small quantity consumed. The quantity of water needed for quality control is dependent upon the characteristics of the waste effluent discharged to the watercourse, the characteristics of the watercourse, and the quality objectives established. When demands for water supply are changed, a change in the requirements for water quality control can be anticipated. Thus, two separate but related volumes make up the needs for water supply and water quality control. The subsequent sections discuss each need separately--Section A concerning water supply and Section B concerning water quality control.



LOCATION OF THE WASHINGTON METROPOLITAN AREA
WITHIN THE POTOMAC RIVER BASIN

FIGURE 106

SECTION A

WATER SUPPLY NEEDS FOR THE WASHINGTON STANDARD METROPOLITAN AREA

GENERAL

The protection of public health through the provision of a safe water supply has long been a matter of primary concern to the public health profession and has been a significant contributing factor to the high health standards of the Nation. However, the problem of providing adequate amounts of safe potable water has become increasingly difficult and expensive due to the pyramiding water demands of rapidly expanding population and industry. Furthermore, the resulting increase in waste flows has caused a gradual degradation in the quality of downstream waters. While improved methods of treatment and disinfection of both wastes and water have served to maintain the quality within tolerable limits, the progress in pollution abatement and water treatment has not kept pace with this population growth and industrial expansion.

The familiar problems of pollution by bacteria, organic matter, and chemicals of known toxicity and behavior have been further intensified and complicated by problems of mineral enrichment due to water re-use and by new types of contaminants associated with our chemical and atomic age. The effects of these newer contaminants on water treatment processes and on the human consumer are largely unknown. These deficiencies in knowledge and the prospect of even greater quantities of yet more complex pollutional materials reaching surface waters emphasize the urgency of intelligent water quality management.

It is sound planning to reserve the highest quality water for highest priority uses. The protection of this quality against irreversible and potentially hazardous degradation must be practiced to the fullest extent possible.

POPULATION STUDY

The total water supply demand of an area is a function of numbers and types of water customers. The basic population study of the general area was prepared by the Department of Commerce, Office of Business Economics. The results of the population study which will be used within this part of the U. S. Public Health Service report are shown in Table 84.

Table 84

Population

Population and Category	Year 1960	Year 1985	Year 2010
Rural Residential			
Maryland	387,500	706,800	700,000
Virginia	212,800	258,000	250,000
District of Columbia	-	-	-
Total Rural Residential	600,300	964,800	950,000
Urban			
Maryland	280,000	820,000	1,769,000
Virginia	305,700	732,500	1,361,000
District of Columbia	747,000	800,700	895,000
Total Urban	1,332,700	2,353,200	4,025,000
Total Population	1,9[illegible],000	3,318,000	4,975,000

RATE OF WATER USE STUDY

The magnitude of increased water use for all major purposes in the United States during the 55-year period (1900-1955) was from 40.2 billion gallons to 262.0 billion gallons per day[1]. The development of American agriculture, industry, and metropolitan growth has been based upon the availability of an abundant and economical water supply of suitable quality. By 1980, water use in the United States for all major purposes is expected to be 494.1 billion gallons per day (bgd), or an increase of 230.3 bgd from 1955. Table 85 shows the water uses by categories as estimated for the United States.

Studies made on public water supplies indicate that there were about 4,000 supplies serving 30 million people in the year 1900; 17,500 supplies serving an estimated 111 million people in 1955; and by 1980 it is expected that 167 million people will be served by public water supplies in the United States. Such supplies furnish water for domestic, commercial, and industrial purposes within their areas of distribution. The studies on water use for the purpose of this report incorporated surveys made by the American Water Works Association, the U. S. Public Health Service, the Water and Sewerage Industry, and the Utilities Division of the Business and Defense Service Administration, U. S. Department of Commerce. From these sources of information on water uses and Census Bureau figures on population, it is found that in addition to increased water demands by direct increases in population, the per capita daily average use of water in the United States is on the increase. National municipal per capita water use in 1958 was about 150 gallons per day. In view of past trends, it is reported that the per capita daily average municipal use is expected to average 192 gallons per day (gpd) by 1980[2].

From a study of 58 municipal systems operated by the American Water Works Service Co., Inc., it was revealed that residential sales of water per service for the years 1939-1956 increased fairly uniformly at the rate of about two per cent per year[3]. It was also indicated that metered residential sales increased with rising family income.

The demand for municipal water supply is created by a number of separate uses such as domestic, commercial, industrial, public and fire protection. Raw water unaccounted for is often overlooked. In

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[1, 2] W. L. Picton, "Water Use in the United States, 1900-1980," Business Service Bulletin, Department of Commerce, (March 1960).

[3] The Task Committee, American Water Works Association, "Study of Domestic Water Use," Jour. of Amer. Water Works Assoc., (November 1958).

estimating the quantity of raw water to meet the above needs, additional volumes are required for such non-cusumer purposes as washing of filters. While not a use, waste through unavoidable leakage must be considered also in order to assure an adequate volume reaching the consumer. It should be kept in mind that the need for municipal water supply shown herein for the raw water supply before delivery to the water treatment plants. Very often, for purposes of developing overall data on municipal water demand, writers have grouped cities by population brackets to determine unit water use. While this method furnishes a general idea of overall quantity of municipal demand, an engineer developing estimates of future water needs of a specified city would look primarily to the characteristics of the city under consideration.

Community habits, standard of living, number and diversity of commercial business establishments, attractiveness to tourists and conventions, public policy with respect to civic duties, size and number of industries within the city, climate, extent of quantity of water supply of good quality, and pressure in the distribution system are the more important of the many considerations that influence the composite unit rate of water use. The past influence of the above considerations is built into historical records.

ESTIMATED DEMAND

In planning the future water supply needs of an area, public health and convenience should receive prime consideration. Estimates of future requirements to meet all foreseeable needs should be made with a reasonable degree of optimism. A rigid interpretation of historical records has, in the past, almost always resulted in an underdesigned water system. In U. S. Senate Committee Print No. 7, page 11, of the Select Committee on National Water Resources, it was stated that the present 147 gallons per capita per day (gpcd) of average municipal use could conceivably increase to about 185 gpcd in 1980 and to 225 gpcd in the year 2000, with a possible leveling off thereafter. It is again emphasized that convenience greatly influences the following water demand estimates, and would reflect an increasingly higher standard of living.

Industrial use of municipally supplied water varies greatly among cities, and each case must be studied individually. Observations made by others show that the industrial use of water may range from zero to over 80 gpcd, based on the entire population of the city. The present municipally supplied industrial use in the Washington Metropolitan Area is probably lower than the national average. However, according to the results obtained from the Economic Base Study, the next 50 years will see increased emphasis and greater employment in the Washington Standard Metropolitan Area in nonfarm commodity-producing industries, with a resulting increase in this use. This optimism is built into the estimated per capita demands shown in Table 86.

Table 85

Water Use in the United States, 1900-1980,
U. S. Department of Commerce

Use Category	Billion Gallons Per Day - Average		
	1900	1955	1980
Irrigation	20.2	116.3	178.0
Rural	2.0	5.4	7.4
Public	3.0	16.3	32.0
Industrial & Miscellaneous	10.0	49.2	115.0
Steam-Electric	5.0	76.6	161.7
Total - All Uses	40.2	263.8	494.1

Table 86

Municipal Water Supply, Estimated Per Capita Use

Category	1960	1985	2010
Rural Residential			
Average	110 gpcd	151 gpcd	192 gpcd
Maximum	165 gpcd	206 gpcd	247 gpcd
Urban			
Average	160 gpcd	185 gpcd	210 gpcd
Maximum	200 gpcd	225 gpcd	250 gpcd

Available information indicates that the rural residential population, whether located in Maryland or Virginia, now uses about 110 gpcd on the average--this reflecting mostly a domestic water use. As larger distribution water mains and sewers become available to this population, it is anticipated that more water-using devices will be added to the homes in the rural areas and that commercial establishments will be attracted to these areas. The increased rate of use is estimated to be 1 1/2 per cent annually for the next 50 years. There will be short periods of greater than the average daily demand, and these could be anticipated especially during the hot dry months when stream flow is low.

The District of Columbia'a experience in rate of water use is representative of the large urban population. This composite use figure, which is composed of the several separate uses previously discussed, represents the present situation. As this urban area is already highly developed, it is anticipated that the rate of increased use will be slower than that of the rural residential area. The increased rate of use is estimated to be one gallon per capita per day annually for the next 50 years. There will also be short periods of demand greater than the average daily demand and such demand could also be anticipated during the hot dry months. Projected rates of water use are shown in Table 86.

The total water supply demand for the area results from applying the rate of use figure to the estimated population, and these quantities are shown in Table 87. Two demand figures have been determined. The average demand figure can be used for the basis of source development if the supply can be drawn from a nearby reservoir in which demand fluctuations can be averaged. If the water is to be drawn from the run-of-river supply, the controls of which are some distance upstream, the safest design would be based on the maximum daily use.

From an inspection of Tables 88 and 89, it can be seen that by about 1987 the deficiency of the present supply would be apparent every day during periods of low flow in the Potomac. As the maximum daily demand usually occurs during the hot dry periods when the river flow is lowest, it would be expected that by about 1977 there would be periods of time during which water rationing practices would be required. On the basis of using all available water for municipal supply, rationing can be expected by 1977. It is pointed out that during such situations, the river would be essentially pumped to dryness, allowing only a trickle of fresh water to flow to the estuary. Under such conditions, the quality of the estuary would be expected to be objectionable.

Table 87

Great Falls and Downstream Municipal Water Supply Demand

Category	1960			1985			2010		
	Population	gpcd	Quantity MGD	Population	gpcd	Quantity MGD	Population	gpcd	Quantity MGD
Water Use Based on Average Per Capita Water Demand									
Rural Residential	600,400	110	66	964,800	151	146	950,000	192	182
Urban	1,332,700	160	220	2,353,100	185	435	4,025,600	210	845
Total Average			286			581			1027
Water Use Based on Maximum Per Capita Demand									
Rural Residential	600,400	165	98	964,800	206	198	950,000	247	235
Urban	1,332,700	200	265	2,353,100	225	530	4,025,600	250	1000
Total Maximum			363			728			1235

Table 88

Present (1960) Available Water Supply

Source	Dependable Supply (MGD)
Potomac River	536
Patuxent River	42
Occoquan Creek	50
Total	628

Table 89

Comparison of Water Supply Demand
and Available Supply in MGD (1)

Year	Average Daily Use Quantity Needed	Quantity Available	Estimated Water Supply Deficit
1960	286	628	-
1985	581	628	-
2010	1027	628	399
	Maximum Daily Use		
1960	363	628	-
1985	728	628	100
2010	1235	628	607

(1) Million Gallons Per Day

SOURCES OF WATER SUPPLY

Surface Water Sources

The study of supplies was limited to possible sources within the study area. It was believed unrealistic to consider either the Rappahannock River to the south, or the Susquehanna River to the north as a source of supply for the study area. It is assumed that each river will receive heavy demands from populations within its own Basin, with no water available for use by adjoining basin populations. The City of Baltimore at the present time has under construction facilities which will tap the Susquehanna River as a major water source, and expansion of use of the Rappahannock River by users within that Basin is anticipated in the near future.

Potomac River

The Potomac River is the second largest river in the Middle Atlantic States. In the vicinity of Great Falls, the drainage area is about 11,460 square miles. Flows at Great Falls have varied from a minimum daily discharge of 506 million gallons per day to flood flow of 275 billion gallons per day, while the annual flow averages about 7100 million gallons per day. The average daily flow of 7100 MGD means only that if the river was to be completely controlled above Great Falls, a daily flow of 7100 MGD would result. The minimum daily flow expected under conditions of minor regulation existing at the present time (536 MGD) is the dependable quantity which can be considered for municipal water supply. It should be remembered that the minimum flow generally occurs during the hot dry season, a period during which the maximum daily demand would be exerted upon the available supply.

As previously reported in Part VI, the quality of the Potomac River at Great Falls is acceptable as a raw water source if followed by conventional water treatment such as now provided for the District of Columbia. With proper upstream control, this quality can be expected to be maintained.

Occoquan Creek

The Alexandria Water Company has fully developed this subbasin. The maximum safe yield from Occoquan Creek is estimated to be 50 MGD. While no additional dependable quantity could be developed from this source, the 50 MGD are expected to be continuously available to help meet the needs of the area.

Patuxent River

The principal source of supply for the Washington Suburban Sanitary Commission prior to 1961 was the Patuxent River. This sub-basin has been developed to its economic limit for water supply. The safe yield is believed to be about 42 MGD. While no additional dependable supply can be developed in this sub-basin, it is assumed that the 42 MGD will be continuously available to help meet the needs of the area.

Estuary

The Potomac below Washington, D. C., is a tidal stream. Salt water content becomes noticeable near Quantico, Virginia. The channel is improved by dredging to accommodate shipping. In general, the estuary is shallow and at low tide, tidal flats are observed. The estuary receives the treated wastes and drainage from the surrounding communities to the extent that during periods of low flow a significant portion of the tidal waters consist of treated wastes.

It has been suggested by others that the estuary could be a source of water supply for the Metropolitan Washington Area, and therefore regulation of the river would not be required. This opinion is based upon complete elimination of polluted materials to the river. The complete elimination of pollution is an ideal objective, but is unlikely to be achieved. Based on knowledge of present water carriage practices, land drainage practices, knowledge of present waste treatment practices, and present capabilities of conventional sand-filter water treatment plants, it is unlikely that a water of satisfactory quality supply could be provided from this source. (Distillation is discussed separately.) Recirculation such as has been proposed by others has been practiced for a short period out of necessity (no alternative available) in one midwestern community (Chanute, Kansas) and the results were not satisfactory.

Distillation

There are two sources of water in the Metropolitan Area which could be used in the distillation process to obtain a water supply. The sources are: (1) saline water, and (2) waste waters.

(1) Saline Water

With retreatment of the distillate, a good water supply could be obtained from saline water. The principal disadvantage of distillation is its very high cost--lowest production costs now are in the range of $1 per thousand gallons, and the finished water would have to be piped about 30 miles to the point of use. The production cost alone is enough to determine that this source is not competitive with surface waters as a municipal supply.

(2) Waste Waters

The principal advantage of reclamation of waste waters is in the location of these waters. Long pipelines and large power demands for pumps would not be needed to deliver the reclaimed water to the point of use. The use of such a supply would materially reduce the demand for other available supplies. Under the present condition of limited industrial development in the area, waste waters from the Washington Metropolitan Area should be suitable for reclamation by distillation in that these waters contain waste mostly from human, animal, and vegetable origin.

The disadvantages of reclamation of waste waters for a municipal supply are the high costs and the reluctance of a population to re-use its own waste water. This reluctance has been called the aesthetic barrier; however, it is assumed that this attitude can be overcome by education.

Much more research must be completed before reliable cost estimates can be made for distilling waste waters. At this time, it is suggested that waste water distillation should be somewhat cheaper than sea water distillation. Several factors involved can be discussed to show the probable range of costs. In terms of crude oil at 10 cents per gallon (150,000 BTU/gallon), the cost of heat for distilling could be as much as 50 cents per thousand gallons. Amortization of capital cost plus the usual other operation and maintenance costs would double or triple these figures. The production cost could therefore be as high as $1.50 per thousand gallons. As in distillation of saline waters, the production cost alone is enough to determine that this source is not competitive with surface water as a municipal supply in the Washington Metropolitan Area.

In addition to high cost, other problems can be anticipated. Where the sewage contains compounds which have a lower boiling point than water, these compounds would carry over into the end product. Carry-over of foam from detergents could be a problem and would require special design to prevent this carry-over. The problems of slime and scale deposit in the evaporator could be anticipated.

Distillation is not carried to dryness but is a continuous process. As a result, the concentrated residue must be disposed of in some way. This would involve either wet oxidation or transport of concentrated sewage by pipeline to a point of disposal, the nearest of which is 30 miles distant. The concentrated residue would be about 2.5 to 10 MGD.

It is reported that waste water could be used for cooling purposes and for pre-heating these waters for evaporation at the same time. Unless the units were so designed, large quantities of heat would be added to the Potomac River. It is not known

how much water is lost to the atmosphere by this process. However, in view of the concentrated residue disposal and evaporation losses, make-up water would be required.

The size of units needed for the purpose of distilling the waste waters would require that large tracts of land in the Metropolitan Area be used for this industrial development. The distillation equipment will be necessarily oversized in order to anticipate shutdowns for cleaning and maintenance, as well as breakdowns. Large daily or seasonal variations in demand would have to be taken care of by storage facilities.

Immerse quantities of fuel would be required, necessitating large railroad yards for both conveyance of coal into Washington and conveyance of ashes away from Washington, if the coal is used. As the technology for recovering energy from nuclear sources improves and at such time as nuclear energy is competitive in price, the fuel supply and ash disposal problems would be solved.

Summarizing, it is believed that distillation of sewage as a water supply would be extremely costly, as well as impractical, as a solution to the Metropolitan Washington water supply problem. The present and foreseeable future high cost of reclaiming waste waters by distillation plus the additional problems which would be created by the distillation industry in the Washington Area such as: (1) the taking of land for the distillation industry, (2) the need for wet oxidation or a 30-mile pipeline system to dispose of concentrated wastes, and (3) the need for make-up water, all present a discouraging picture of the feasibility of reclaiming waste waters for a municipal water supply in the Washington Metropolitan Area. Further consideration of such re-use awaits a technical breakthrough.

Ground Water Sources

The U. S. Geological Survey had developed an extensive report on the availability of ground water within a 50-mile radius of Washington. Information shown within this discussion has been drawn from the Geological Survey Report.

The potential yield* of aquifers which could be made available as a supplementary water supply for the Washington Metropolitan Area is over 400 MGD. Only 240 MGD will be considered for water supply, as aquifers which provide the remaining 160 MGD are not adequately explored. Data on quality indicate that the 240 MGD of ground water are suitable for a municipal water supply if the iron content is reduced by treatment.

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* The perennial withdrawal of ground water at rates equal to the rates of natural replenishment. Ground water resources already being used in the Baltimore, Maryland, area are not included within the 240 MGD estimate.

In the Coastal Plains of Maryland within a 50-mile radius, there are five formations which are considered capable of large or moderately large development. These are the Patuxent with a yield of 45 MGD, the Patapsco and Raritan with a combined yield of 70 MGD, the Magothy with a yield of 8 MGD, and the Aquia Greensand with a yield of 60 MGD. The five formations are briefly discussed below:

(1) The Patuxent well field would be long (38 miles)and narrow (one well wide), and would be located in Anne Arundel and Prince Georges Counties, Maryland, and in the District of Columbia. To intercept the 45 MGD of water probably available, it would be necessary to drill 104 wells pumping an average of 300 gpm each. Wells would be spaced about 2000 feet apart. A pipeline 38 miles long (200,000 feet) would be required to collect this water. Recognizing that the pipeline would be of several sizes, the average size is estimated to be 36 inches in diameter. Using an average cost of $30 per foot, the pipeline alone is estimated to cost $6 million. The wells alone are estimated to cost $621,000. Other costs not estimated would include pumps, well houses, power lines, operation and maintenance, land, and rights-of-way.

(2 and 3) The Patapsco-Raritan well field in Anne Arundel County is estimated to have a potential yield of 70 MGD. The proposed well field would be laid out along two lines, one of 12-mile length and the other of 18-mile length. The pipeline connecting the 166 wells would be 30 miles long with wells spaced 1000 feet apart. As this field is 13 miles from the District of Columbia line, an additional pipeline 13 miles long would be required to deliver the water to the point of use. The pipeline cost is estimated to be over $10 million, and the cost of wells alone is estimated to be $679,000. Again, no cost estimates are available for pumps, well houses, power lines, operation and maintenance, or land and rights-of-way.

(4) The Magothy well field would be about 25 miles long, and have 37 wells spaced at more than 3500 feet apart. In addition to the pipeline connecting the wells, a pipeline 11 miles long would be used to convey the 8 MGD yield to the District of Columbia.

(5) The Aquia well field would be 13 miles long with 116 wells spaced about 600 feet apart. In addition, a pipeline 37 miles long would be needed to convey the 60 MGD of water to the point of use.

The Potomac group in Virginia has a recharge area of about 115 square miles and a theoretical yield of about 57 MGD. To develop this amount would require a well field 48 miles long with a pipeline connecting 132 wells spaced about 2000 feet apart.

The Newark group crops out over about 140 square miles in Maryland, and 480 square miles in Virginia. The combined areas total 620 square miles and have a gross theoretical yield of 124 MGD. To recover all of the water would require a network of 225 wells pumping at the rate of 800 gpm. These aquifers have not been adequately explored. The water from this group may have a hardness approaching 1000 ppm where the quantity is adequate.

The Cockneysville Marble has an outcrop area of 58 square miles within the 50-mile radius. If fully developed, the formation has a potential yield of about 17 MGD and would require about 170 wells for full development.

From the figures presented in Table 90 , it can be seen that the development of a supplementary municipal water supply would be expensive both in capital cost and operation and maintenance. There would be 555 wells and about 215 miles of pipeline. The well field would cover a very large area and with the spacing indicated, problems would arise such as protection, power supply, stand-by power facilities, and maintenance. For these reasons, it is concluded that the development of ground water as a supplementary supply for the Washington Metropolitan Area would not be competitive in cost with surface water, as well as being impractical.

There are also valid reasons why this ground water should be reserved for development in small local units for municipal and industrial purposes. The ground water may be the only source available to such communities and heavy pumping by the Washington Metropolitan Area would deprive them of the only source of supply practical for their development. Ground water is nearly constant in quality, and in the subject area it is of satisfactory quality for most ordinary uses without treatment. As delivered at the wellhead, ground water is generally constant in temperature. This last fact and its widespread availability without long pipelines make it particularly desirable for local and industrial uses.

DISCUSSION

It is recognized that water for human consumption holds the highest priority of all water uses. Where alternate sources are available, it is sound planning to reserve the source of supply with the best quality of water for municipal supply.

Conversely, it is not sound planning to compare the cost of one water supply having a barely satisfactory quality with one of somewhat higher cost which has an excellent quality, and then choose the cheaper supply of minimum quality without considering the advantages of the higher quality water supply.

Table 90

Well Field Yield

Formation	Number of Wells	Spacing (Feet)	Total Pipeline Length (Miles)	Yield (MGD)
Patuxent	104	2,000	38	45
Patapsco-Raritan	166	1,000	43	70
Magothy	37	3,500	36	8
Aquia	116	600	50	60
Potomac Group	132	2,000	48	57
Sub-Total	555		215	240
Newark Group	225	Unknown		124
Frederick and Grove Limestone	316	Unknown		22
Cockneysville Marble	170	Unknown		17
Total	1,266			403

If it would be possible to obtain both the highest quality of water of the quantity needed at the smallest unit cost of all supplies considered, then the selection or recommendation as to the best source for the municipal supply would be greatly simplified.

Consideration of surface water sources shows that Occoquan Creek and Patuxent River have been completely developed and that no additional dependable water supply is available from these two watersheds. Neither the Rappahannock nor the Susquehanna are considered as likely sources for the Metropolitan Area since each basin eventually will be developed to serve population within it. The upper tidal estuary and the Potomac River above tidewater are the last two freshwater surface supplies to consider.

The upper tidal estuary consists of effluents from several sewage treatment plants, uncontrolled drainage from city streets and other urban areas, and the unused waters from the free-flowing Potomac River. The resultant normal estuary quality is inferior to the free-flowing river water quality, and is further degraded during periods of low flow. Treatment of this water to provide a safe quality, as well as aesthetically acceptable supply, would be difficult if not impossible to achieve. This would be especially true during periods of low flow when the water supply would be merely recirculated. In practice, recirculation has been observed to be unsatisfactory.

Ground water, while available, is believed to be an impractical solution due to immenseness of well field area and number of wells required.

Distillation of both salt water and sewage has been considered and rejected on the basis of cost and technical problems unsolved at this time. It is further pointed out that distillation of sewage is in the experimental phase. A prudent designer uses methods that are workable at the present time.

CONCLUSION

The main stem Potomac River meets the test of the highest quality of available water, a dependable quantity if storage is provided, and would be the least costly source of supply to develop. Other sources have been considered and rejected as too costly, impractical, or of poor quality. The main stem Potomac appears to be the logical source of water supply for the Metropolitan Washington Area, and needs only storage structures in order to insure a safe and adequate quantity for the Metropolitan Area.

It is believed that with or without reservoir construction, the quality of water available for Metropolitan Washington municipal supply will be under increasing pressure due to the following developments in the upstream areas:

1. Increasing use of fertilizers, insecticides, and weedicides in the upstream areas.

2. Increasing population.

3. Increasing industrialization.

4. Increasing use, necessitating more re-use at low-water stages.

However, present investigations of wastes, waste treatment and removal, in combination with river flow control indicate that water coming into the Metropolitan Washington Area can be maintained at a quality level equal to or better than the present quality, even after predicted upstream industrial expansion has taken place. This is predicted on the assumption that presently known methods of quality control are employed effectively and fully. The machinery to carry out such a program has been set in motion and there is no good reason why it cannot be realized.

With respect to the River Bend (or Seneca) Reservoir, storage of water of the anticipated incoming quality would tend to improve rather than degrade it. Bacteria would be markedly reduced in numbers, oxygen consuming substances would undergo greater stabilization, sediment would be reduced, radioactivity decreased, and inorganic matter evened out by the aging and averaging effect of storage. The only exception may be an increase in algae production because of greater opportunity for photosynthesis brought about as the result of the clarification and increased sunlight penetration. This is not viewed as a serious problem and can be controlled on the site if necessary. All water supply structures would be expected to have multiple-level intakes to enable the taking of water from the level of best quality.

Adequate continued protection of the quality of water must be provided. The construction of the large Potomac River interceptor sewer to serve communities on both sides of the Potomac River will prevent the entrance of sewage and industrial wastes into the Potomac River through the reservoir reach. Sanitary requirements for the anticipated development on the reservoir must be laid out and maintained rigidly.

SECTION B

NEEDS FOR FLOW REGULATION FOR WATER QUALITY CONTROL IN THE POTOMAC RIVER ESTUARY

GENERAL

The purpose of the phase of the study reported herein was to determine the effect of the river discharge of the Potomac River on the waste assimilation capacity of the river system at and near Washington, D. C.

The Potomac estuary is a highly complex tidal system. The river in this area has a tidal range in height of about three feet, but is above the region of noticeable salt intrusion. The river discharges (except at very high flows) are swallowed up in the tidal system--water motion in this region is dominated by the tide. Wastes discharged near Washington can remain in the vicinity for some time. During this time large quantities of oxygen are consumed and a vast supply of nutrient materials are provided for aquatic organisms. Some of the waste load may be passed on to the sea, but a large part of the oxygen demand of these wastes must be satisfied in the upper reaches of the Potomac estuary, principally in the reach from Georgetown to Fort Foote.

This region has been sampled routinely since 1938 by the District of Columbia Sewage Treatment Plant personnel. Samples have been taken on a weekly to monthly basis at several stations in the estuary since that time. While this large body of data are extremely useful in characterizing the changes in water quality which have occurred during the 20 years of sampling, the results of that sampling program do not form a suitable experimental base for determination of the effects of river discharge on the waste assimilation capacity of the system. Since the estuarine regime is dominated by semidiurnal tidal effects and diurnal algal effects, a suitable experimental base for securing the objectives of this study must include sampling at a rate fast enough to permit the resolution of these effects.

Because of the complexity of the system and the specific objectives of this study, an intensive field survey of six weeks duration was designed, and was conducted in July and August 1959. The large quantity of data developed and the information required from these data necessitated the use of statistical and analytical techniques not used previously in sanitary engineering studies. This section summarizes the results of the field study in a primarily qualitative manner.

DESCRIPTION OF THE FIELD STUDY

The field study consisted of four general phases which are discussed separately below.

TEMPERATURE AND DISSOLVED OXYGEN CROSS-SECTIONS

The measurements of temperature and dissolved oxygen variations within single cross-sections of the estuary were undertaken to determine the extent and character of stratification in the reach under study. Thirteen locations from the Three Sisters Island to below Fort Washington were sampled twice before the main sampling program was begun. Each cross-section was sampled once on the ebbing tide and once on the flooding tide. From each section, 7 to 14 samples were taken, depending on the size of the section. This entire procedure was repeated after the main sampling program was concluded.

The results of this phase of the study showed that no strong and coherent pattern of stratification could be postulated for this river reach. While there were differences in dissolved oxygen and temperature within a single cross-section, these variations were generally not consistent and were mostly within the range of sampling variability.

BIOLOGICAL STUDY

Near the close of the main sampling program, a Public Health Service biologist made a brief survey of the bottom biota in the study area. The results generally indicate that the biota are those associated with a high degree of pollution. Sludge banks were found in the vicinity of sewage outfalls and near the mouth of Rock Creek.

SLACK TIDE SAMPLING

In order to determine the locations of the maximum pollution areas at slack tides, two slack tide runs up the river were made at the close of the survey. On these runs a series of mid-channel, mid-depth samples were taken as the boat rode the slack tide upriver. The temperature, dissolved oxygen, and biochemical oxygen demand of each sample were measured. On ebb slack a run was started at Fort Washington and proceeded to Fort Foote before the slack was lost. On flood slack a run was started at Giesboro Point and proceeded up the Anacostia to the Sousa Bridge before the slack was lost.

The greatest BOD at ebb slack was found about halfway between Fort Foote and Fort Washington, corresponding generally to the limits of a tidal excursion downstream from the Blue Plains outfall. At flood slack BOD increased from Giesboro Point all the way to the Sousa Bridge. This is well beyond the limits of a tidal excursion from the Blue Plains outfall.

TIME SERIES SAMPLING OF RIVER STATIONS

This phase of the field study provided the main body of data on which the estimates of waste assimilation capacity are based. Nine representative points in the system were selected for sampling, and at each point 145 samples were scheduled to be taken at four-hour intervals. These points are shown on Figure 107.

On each sample measurements of temperature, dissolved oxygen (D.O.) and biochemical oxygen demand (BOD) were made by the Public Health Service staff operating from a mobile laboratory located at the District of Columbia Sewage Treatment Plant. Resources Research, Inc., a consulting firm retained by the Government of the District of Columbia, ran MF coliform counts, algal counts, solids, phosphates, and turbidities on the time series samples. Records of tide height, solar radiation, river discharge, and waste volume discharges were also obtained.

ANALYSIS OF DATA

The criterion used as the measure of the waste assimilation capacity of this system is the level of dissolved oxygen which can be maintained in the stream while it is receiving a given daily decomposable waste load.

If the waste load was the only factor which affected the dissolved oxygen content, the estimation of waste assimilation capacity would be a relatively simple problem. Unfortunately, the dissolved oxygen content (D.O.) as observed in the stream is the result of the interplay of many driving forces, some of which tend to remove dissolved oxygen and some of which tend to add oxygen to the water. Figure 108 is a simplified schematic representation of the major driving forces which affect the dissolved oxygen in this particular system.

This figure illustrates that while the internal workings of this system are quite complex, the observed stream D.O. is controlled by the operation of four primary driving forces. These are:

(1) Solar Radiation

(2) Total Waste Load

(3) River Discharge

(4) Tide

These primary driving forces differ in both character and magnitude in their effects on stream dissolved oxygen. It may be noted that there are direct effects, such as the production and

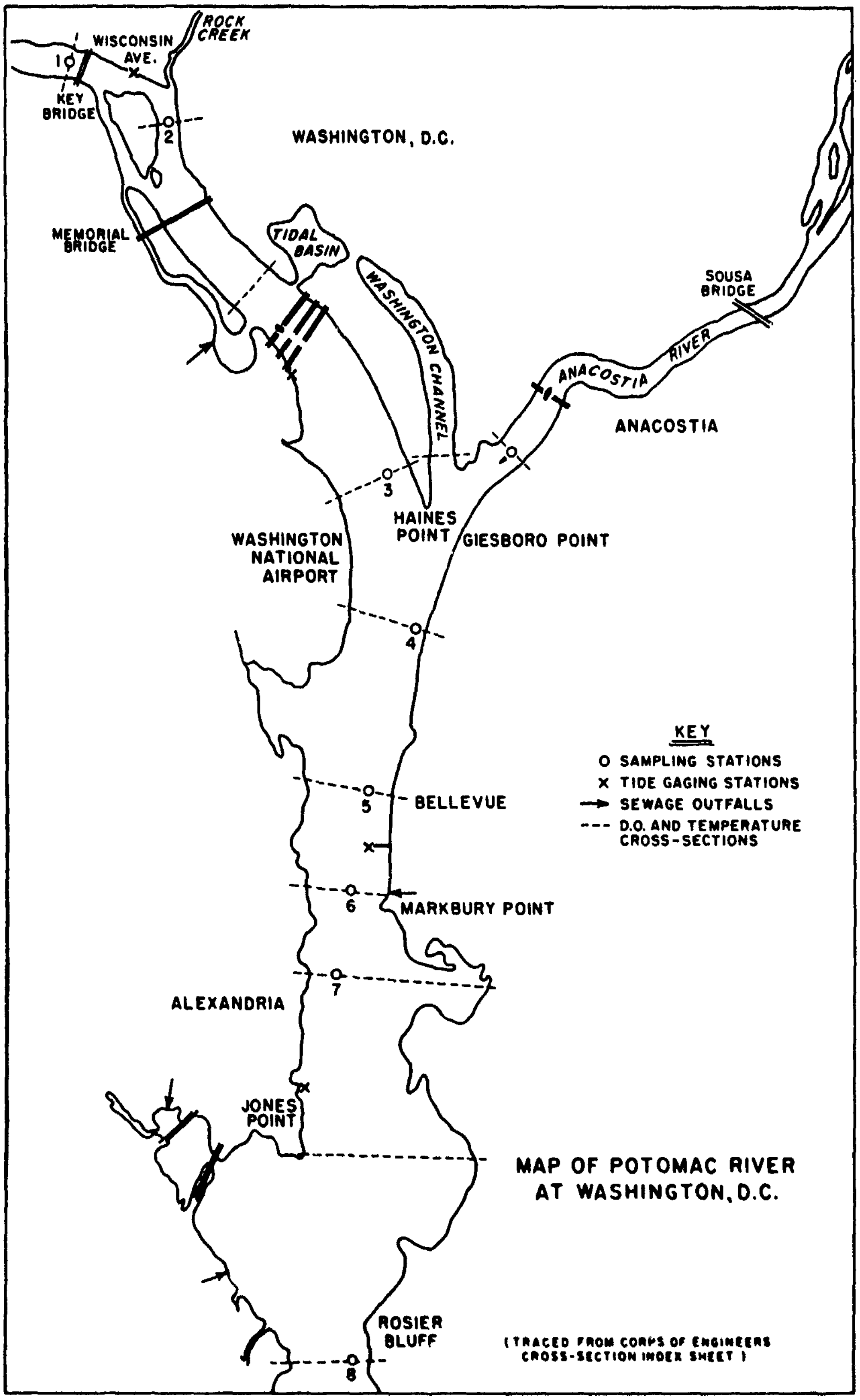
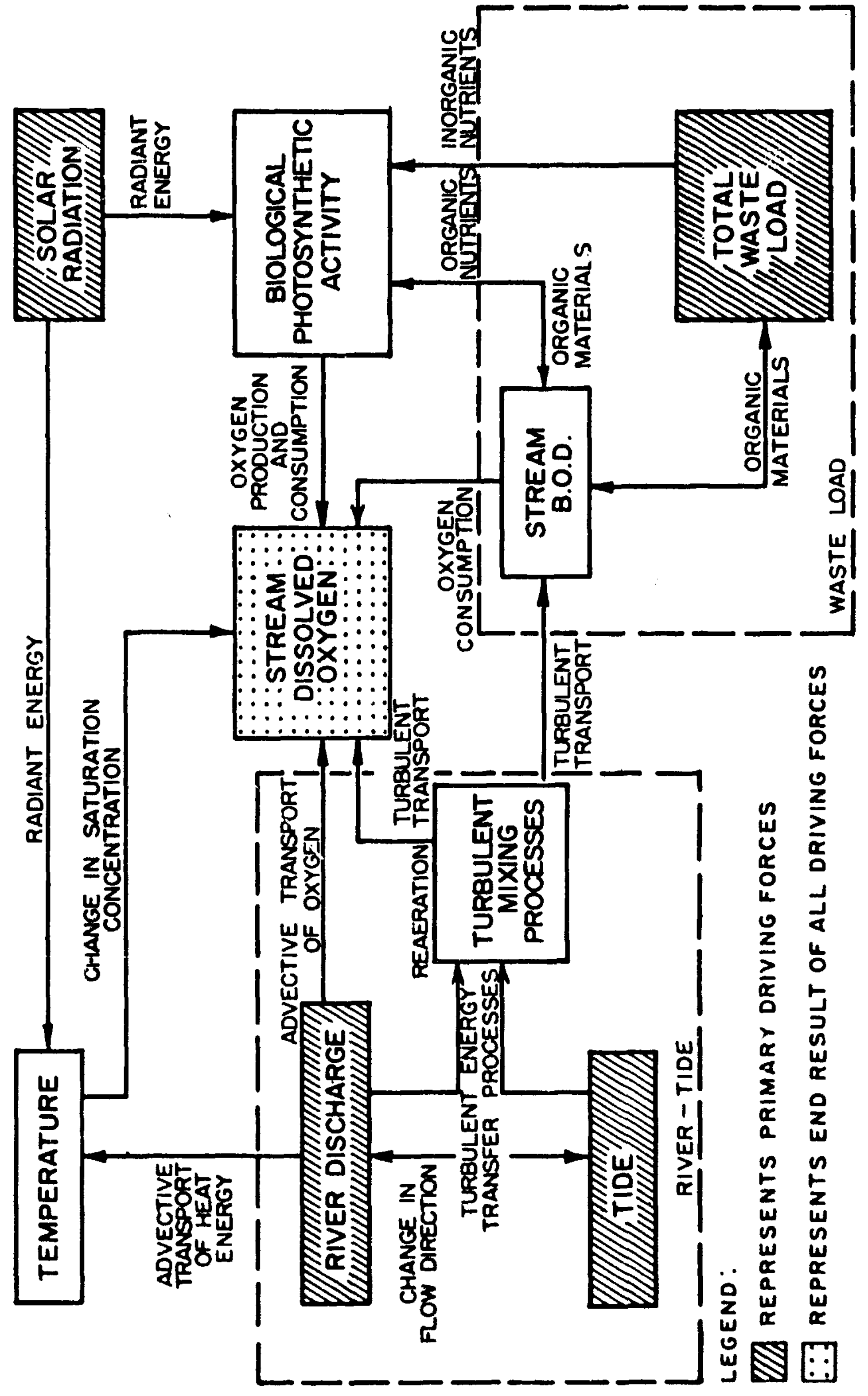

ROCK CREEK
WISCONSIN AVE.
KEY BRIDGE
1
2
WASHINGTON, D.C.
MEMORIAL BRIDGE
TIDAL BASIN
WASHINGTON CHANNEL
SOUSA BRIDGE
ANACOSTIA RIVER
ANACOSTIA
3
HAINES POINT
GIESBORO POINT
WASHINGTON NATIONAL AIRPORT
4
KEY
O SAMPLING STATIONS
X TIDE GAGING STATIONS
SEWAGE OUTFALLS
--- D.O. AND TEMPERATURE CROSS-SECTIONS
5
BELLEVUE
6
MARKBURY POINT
7
ALEXANDRIA
JONES POINT
MAP OF POTOMAC RIVER AT WASHINGTON, D.C.
ROSIER BLUFF
8
(TRACED FROM CORPS OF ENGINEERS CROSS-SECTION INDEX SHEET)

FIGURE 107



FACTORS AFFECTING STREAM DISSOLVED OXYGEN CONCENTRATION

FIGURE 108

consumption of oxygen through biological action, and that there are indirect effects, such as the changes in turbulence due to river discharge and tidal action, which result in D.O. changes in reaeration capability. It may also be seen from Figure 108 that there is a strong interaction between river discharge and tide for this tidal system. The interaction is so pronounced that the tidal height is affected by river discharge as well as tidal forces.

The general approach used in the analysis of the field survey data has been to regard the observed D.O. fluctuations in the stream as resulting from the effects of the prime driving forces as measured by solar radiation intensity, tidal height-river discharge, and stream BOD, which is a measure of the total waste load. The techniques used in the data analysis were chosen because they supplied a procedure for calculating the stream D.O. response to each of these parameters.

The dissolved oxygen response observed during the survey was used to estimate waste assimilation capacities and reaeration rate constants for the river discharges observed during the survey. The reaeration rate constant values for river discharges over the range 800-5000 cubic feet per second were then used to estimate the corresponding waste assimilation capacities for a mean minimum D.O. of 5.0, 4.0, and 3.0 parts per million.*

DISCUSSION OF RESULTS

The results of the data analysis showed the dominance of diurnal and semidiurnal effects on this system. In general, the semidiurnal effects could be attributed to the results of water motion due to tidal action and river discharge, while the diurnal effects could be attributed to the effects of sunlight and diurnal waste load variations.

From the stream D.O. records and records of stream BOD, solar radiation, river discharge, and tide height, the response of stream D.O. to each of these driving forces was estimated by the methods of spectral analysis. These methods also provided factors which were used to remove the interference of algal oxygen production and consumption from the D.O. response to stream BOD.

From the stream D.O. responses so calculated, the response of D.O. to the river discharge was obtained directly by adding together the D.O. responses to changes in the appropriate river discharge and

* These values represent the mean D.O. for the months of minimum flow; because of the wide diurnal fluctuations in D.O. attributable to variations in photosynthetic activity, the absolute minimum D.O. corresponding to these average values will be 3, 2, or 1 parts per million, respectively.

tidal height parameters. This same response of D.O. to river discharge was also obtained indirectly by subtracting from the total stream D.O. response the sum of the D.O. responses to sunlight and stream BOD as corrected for algal effects.

As a check on this procedure, an oxygen-sag analysis was carried out using a deoxygenation rate constant consistent with the results of ten long-term BOD's run during the survey. The daily mean values of the stream station parameters were used for this calculation, and the reaeration rate constants calculated by this procedure were converted to parts per million of D.O. increase per 1000 cubic feet per second increase in river discharge, a term compatible with those factors derived from the spectral analysis. While this type of analysis does allow for the effects of changes in stream BOD, it does not allow for the effects of algal oxygen production and, therefore, attributes the entire increase in stream D.O. to changes in the reaeration rate constant.

An additional check on these calculations was made by simply plotting the stream D.O. as a function of river discharge and attributing the entire change in stream D.O. to the river discharge. This approach includes in the assumed effects of river discharge the sum total of the counterbalancing effects of changes in algal oxygen production and changes in stream BOD.

The D.O. response factors estimated in these four different ways are presented in Table 91. The values presented are those mean values obtained for stations in the most polluted reach of the system.

Since the response factors derived from spectral analysis have had the effects of algal oxygen production at least partially removed, they are regarded as the most reliable estimates of the response of stream D.O. to river discharge. For estimating the waste assimilation capacity of the system, the mean of these two results (1.01 ppm D.O./1000 cfs) is used.

The stream D.O. response factor was used to calculate reaeration rate constants for the river discharge range observed during the survey. Since the range of discharge observed during the survey was from 1200 to 3600 cfs, the linear extrapolation of reaeration rate constant values to discharges of 800 to 5000 cfs is regarded as reasonably accurate. From the reaeration rate constants so calculated, the waste assimilation capacities at various discharges were estimated using the oxygen-sag formulation. These results are presented in Table 92 and Figure 107 for the mean stream temperature during the survey and for mean minimum D.O.'s of 5, 4, and 3 ppm.

Table 91

Comparison of Stream D.O. Response to River Discharge Calculated in Different Manners

Approach	Stream D.O. Response (ppm D.O./1000 cfs)
Spectral Analysis, Direct	0.96
Spectral Analysis, Indirect	1.05
Oxygen-Sag Analysis	1.41
Direct Plotting of River Discharge vs. Stream D.O.	1.15

The waste assimilation capacity at other temperatures may be estimated by correcting the deoxygenation rate constant for the effects of temperature. This was done for a temperature range of 2 to 25 degrees centigrade; these results are also presented in Table 92.

The figures presented in Table 92 are estimates of the total waste assimilation capacity of the Potomac estuary at Washington. Waste load brought downstream by the river should be included in estimates of the total waste loading of the estuary.

OBJECTIVES

Water quality criteria for the Potomac River in the Washington Metropolitan Area were adopted by the Interstate Commission on the Potomac River Basin on January 22, 1958. As the States of Maryland and Virginia refer to the above-adopted criteria, these have been used as objectives in this report.

In order to meet these criteria, it is believed that in addition to necessity for waste collection and treatment, control of storm water overflow and such other land control measures as regulatory agencies require, there is and will be a need to provide a minimum flow to receive and assimilate treated wastes. In Table 93 estimates have been made of both natural and man-made waste loads which enter the Potomac River estuary. These loads were based on stream survey results, an assumption of waste treatment efficiencies in removal of organic loads, and population projections furnished by the Office of Business Economics.

Table 92

Waste Assimilation Capacity of the Potomac River at Washington, D. C.

River Discharge (cfs)	1,000	2,000	3,000	4,000	5,000	
Temperature (°C.)						
2	260,000	660,000	1,050,000	1,450,000	1,840,000	
5	200,000	510,000	810,000	1,120,000	1,420,000	
10	134,000	340,000	540,000	740,000	940,000	Mean
15	90,000	230,000	360,000	490,000	630,000	Minimum*
20	60,000	150,000	240,000	330,000	420,000	D.O. =
25	40,000	102,000	160,000	220,000	280,000	4.0 ppm
29	29,000	72,000	116,000	160,000	200,000	
2	290,000	730,000	1,160,000	1,600,000	2,030,000	
5	230,000	570,000	900,000	1,240,000	1,580,000	
10	150,000	380,000	610,000	840,000	1,070,000	Mean
15	104,000	260,000	420,000	570,000	730,000	Minimum*
20	72,000	180,000	290,000	400,000	500,000	D.O. =
25	50,000	120,000	200,000	270,000	350,000	3.0 ppm
29	36,000	91,000	146,000	200,000	255,000	
2	240,000	600,000	950,000	1,300,000	1,700,000	
5	180,000	440,000	700,000	970,000	1,200,000	
10	114,000	290,000	460,000	630,000	800,000	Mean
15	74,000	187,000	296,000	410,000	520,000	Minimum*
20	48,000	121,000	192,000	265,000	340,000	D.O. =
25	31,000	78,000	124,000	170,000	216,000	5.0 ppm
29	21,000	53,000	85,000	117,000	149,000	

Table entries are lbs. BOD_5 per day

*Monthly mean for month of lowest D.O. values.

Table 93

Total Pounds of 20° BOD_5 Received in Potomac River Estuary Per Day 1960-2010

Populations, Waste Loads, and Required Stream Flow	1960	1985	2010
Populations Served (Sewerage)			
Maryland	667,500	1,526,800	2,469,000
Virginia	518,500	990,500	1,611,000
District of Columbia	747,000	800,700	895,000
Total Served	1,933,000	3,318,000	4,975,000
Waste Treatment			
Percent BOD_5 Removal	80	85	90
Municipal Effluent Received P.E. Per Day	385,000	497,000	497,000
Upstream Waste Residual(1) P.E. Per Day	57,000	85,000	110,000
Upstream Natural Residual(2) P.E. Per Day	48,000	48,000	48,000
Total P.E. Received in Potomac Estuary	490,000	630,000	655,000
Total Pounds 20° BOD_5 received in Potomac Estuary Per Day	83,500	106,000	111,000

Note: Populations projected by Office of Business Economics.

(1) from upper basin study

(2) estimated from stream survey results

Table 94

Regulation for Water Quality Control - Flow in cfs(1)

Total Pounds 20° BOD_5 Received in Potomac Estuary Per Day	Flow Required to Attain Dissolved Oxygen Objectives as Indicated		
	5 ppm	4 ppm	3 ppm
83,500	2,950	2,230	1,860
106,000	3,650	2,700	2,270
111,000	3,750	2,810	2,360

(1)Month of lowest dissolved oxygen values when temperature is 29°C and recognizing variations of 2 ppm due to photosynthetic activity.

The loads estimated and shown in Table 93 were used to enter Table 92 for determination of flows which would be needed to attain certain dissolved oxygen objectives. These results are shown in Table 94. With treatment as indicated, flows as shown in Table 94 achieve the 5 ppm objective, and monitoring of quality as presently practiced, the observed estuary water quality should approach very closely the established objectives.

The water quality criteria were adopted after a thoughtful consideration of the uses of the Potomac River to which people of the area may aspire within the foreseeable future. These quality objectives are considered reasonable and can be reached with present knowledge of treatment of wastes if flow regulation of the magnitude indicated is provided.

In addition to the flow* needed to achieve the established water quality objective of 5 ppm dissolved oxygen, flows needed to achieve a quality of water somewhat inferior to the adopted criteria are also shown in Table 94. The flows needed to achieve the 4 ppm dissolved oxygen objective should achieve the quality objectives the majority of the time. The flows needed to achieve 3 ppm dissolved oxygen are the minimum flows necessary to assure no nuisance conditions. In the footnote of Table 94, it is reported that a variation

* Flow required during the critical month. The average flow needed modified by temperature is a smaller quantity.

of 2 ppm dissolved oxygen can be expected due to photosynthetic activity. During such activity, with a 3 ppm objective it can be expected that the dissolved oxygen content will decrease to 1 ppm. That quantity is a very small safety factor between no nuisance and nuisance conditions.

It is also pointed out that quantities indicated as needed for quality control were developed considering the most adverse temperature conditions. Information relating to flows needed during less critical months has been previously furnished to the Corps of Engineers in order that storage requirements may be developed.

SUMMARY OF NEEDS

The summary of needs for municipal water supply and flow regulation for quality control in the Washington Metropolitan Area is shown in Table 95, and the same data are shown in Figure 109, Summary of Water Needs. By inspection of both Table 95 and Figure 109, it can be seen that there are immediate needs for flow regulation for quality control on a firm basis, while the dependable quantity available for water supply is sufficient until about 1987 during periods of average daily use.

The Potomac River can be described as a flashy river, i.e., there are great extremes between minimum, average, and maximum flows. It is because of this irregularity of flow that the needs of the Metropolitan Area are not now more apparent and are masked from the layman. On a frequency basis, the needs are often met at the present time for both water supply and quality control. A prudent designer looks to the worst conditions and then shows the quantities needed on a firm basis to satisfy needs under adverse conditions. The needs of the Washington Metropolitan Area can be firmed up by storage structures within the Potomac River Basin.

It is understood that storage requirements to meet the several needs will be computed by the Corps of Engineers, and that a flow study has been made concerning the frequencies and durations of time that needs could be satisfied with several storage capacities in order that an optimum storage capacity can be shown.

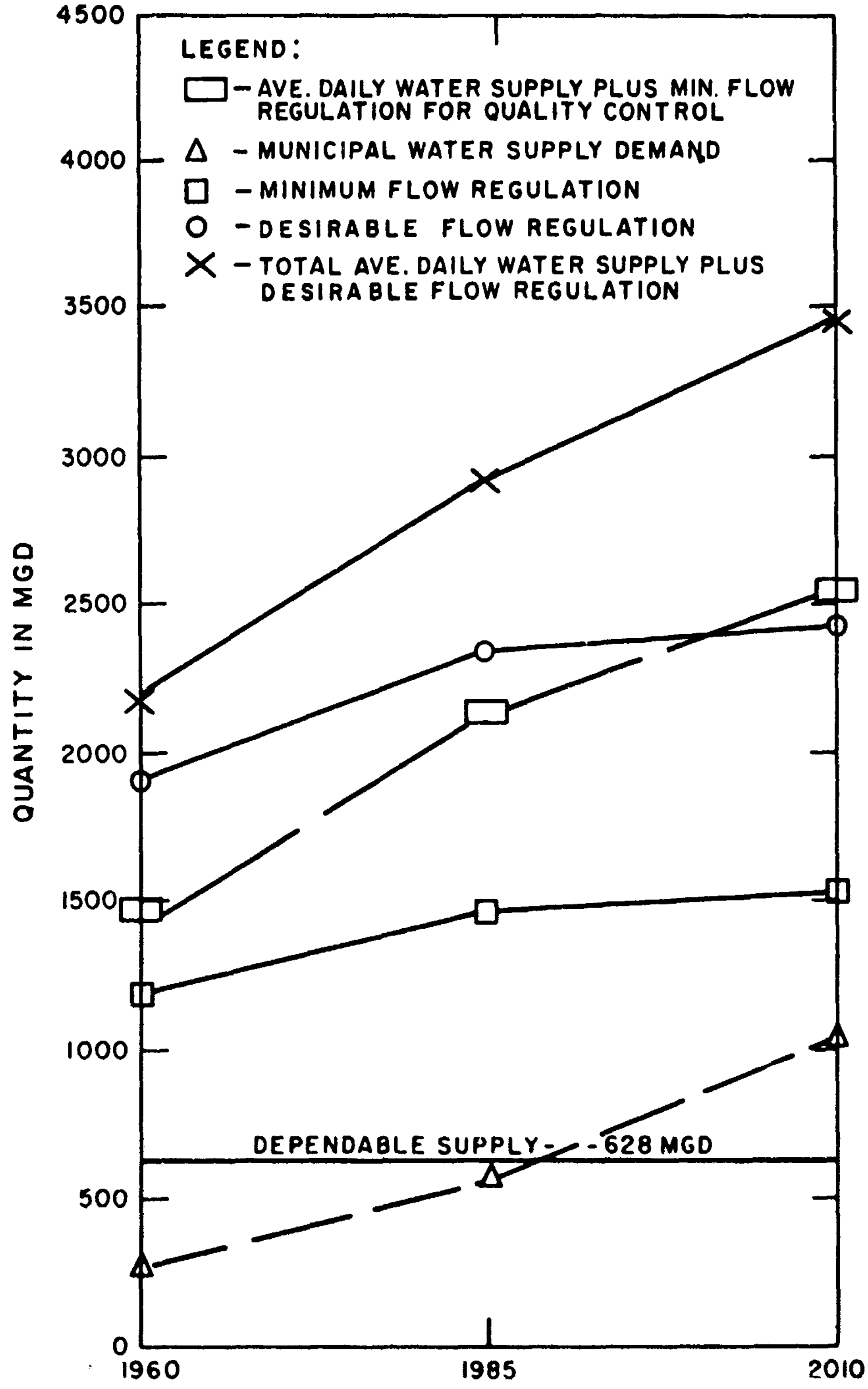
Table 95

Summary of Needs for Municipal Water Supply and Flow Regulation for Quality Control in the Washington Metropolitan Area (Million Gallons Per Day)

Year	Minimum Dependable Supply*	Municipal Water Supply Need Daily Average	Water Quality Control Need		Total Needs		Deficiency	
			Desirable	Minimum	Desirable	Minimum	Desirable	Minimum
1960	628	286	1,910	1,200	2,196	1,486	1,568	858
1965	628	581	2,360	1,470	2,941	2,051	2,313	1,423
2010	628	1,027	2,420	1,530	3,447	2,557	2,819	1,929

*Potomac River, Occoquan Creek, and Patuxent River.

N.B. - The accuracy of the above figures does not warrant the refinement of odd numbers such as 3,447. It is believed that 3,400 would be a more acceptable number; however, to reconcile numbers shown in various tables, it was decided to use numbers as added.



SUMMARY OF WATER NEEDS
WASHINGTON METROPOLITAN AREA

FIGURE 109

Criteria for Sections III, IV, and V are shown below:

SECTION III

POTOMAC RIVER: LITTLE FALLS TO KEY BRIDGE

Objective: The elimination of sewage and waste effluent and excessive soil erosion so that the water will be suitable for swimming, boating, shore recreation, and safe for all species of fish life with favorable conditions prevailing for their propagation.

Criteria: The water quality shall be held in the normal, natural condition of the stream, with nearly all samples falling within the following limits:

1. Coliform Group: MPN not to exceed 2000 per 100 ml.
2. pH: Range between 6.5 and 8.5.
3. D.O.: Monthly median not less than 6.5 ppm, with no D.O. below 4.0 ppm.
4. Turbidity: After opportunity for good mixing in the river, turbidity of the stream should not be appreciably changed.
5. Other Conditions: There shall be no oil, floating solids, settleable solids, or sludge deposits attributable to sewage, industrial wastes, or other wastes. There shall be no toxic wastes, deleterious substances, colored or other wastes or heated liquids, taste or odor producing substances, either alone or in combinations, in sufficient amounts to be injurious to fish life or to make the waters unsafe for swimming, or shore recreation.

SECTION IV

POTOMAC RIVER: KEY BRIDGE TO FORT WASHINGTON

Objective: To reduce the quantity of combined sewage discharged, and to control the quality of waste effluents by effective treatment so as to make the water suitable for boating, shore recreation, industrial water supply and safe for the passage of all species of fish, with favorable conditions prevailing for the propagation of the hardier types.

Criteria: The water quality shall be maintained so that the results of most of the samples fall within the following limits:

1. Coliform Group: MPN not to exceed 10,000 per 100 ml.
2. pH: Range between 6.5 and 8.5.

3. D.O.: Monthly average not less than 5.0 ppm, with no D.O. below 4.0 ppm.

4. Turbidity: After opportunity for good mixing in the river, turbidity of the stream should not be appreciably changed.

5. Other Conditions: There shall be no floating solids, oil, settleable solids, or sludge deposits attributable to sewage, industrial wastes or other wastes. There shall be no toxic wastes, deleterious substances, colored or other wastes or heated liquids, taste or odor producing substances, either alone or in combinations, in sufficient amounts to make the waters unsafe or unsuitable as a source of industrial process water supply, or for boating, shore recreation, passage of all species of fish or propagation of the hardier species of fish.

SECTION V

POTOMAC RIVER: FORT WASHINGTON TO HALLOWING POINT

Objective: To reduce the quantity of combined sewage discharged and to control the quality of waste effluents by effective treatment of wastes and disinfection of effluents to make the water suitable for boating, fishing, swimming, and other recreational uses.

Criteria: The water quality shall be maintained so that the results of most of the samples fall within the following limits:

1. Coliform Group: MPN not to exceed 2000 per 100 ml.

2. pH: Range between 6.5 and 8.5.

3. D.O.: Monthly average not less than 6.5 ppm with no D.O. below 4.0 ppm.

4. Turbidity: After opportunity for good mixing in the river, turbidity of the stream should not be appreciably changed.

5. Other Conditions: There shall be no floating solids, oil, setteable solids, or sludge deposits attributable to sewage, industrial wastes or other wastes. There shall be no toxic wastes, deleterious substances, colored or other wastes or heated liquids, taste or odor producing substances, either alone or in combinations, in sufficient amounts to be injurious to fish life or to make the waters unsafe or unsuitable for swimming, fishing, or other recreational uses.

PART VIII

BENEFITS TO WATER SUPPLY AND POLLUTION
ABATEMENT IN THE POTOMAC RIVER BASIN AND
TRIBUTARIES, EXCLUDING THE NORTH BRANCH POTOMAC RIVER

INTRODUCTION

This part identifies stream reaches benefiting from stored water and enumerates benefits assignable to major reservoirs considered for water supply, water quality control, and cooling purposes that will accrue by flow regulation in the Potomac River Basin. The benefit analyses presented are based on present and future requirements for water supply and flow regulation as described in Parts V, VI, and VII of the Potomac River Basin Study Report.

Request for this and prior study parts was made by the U. S. Army Corps of Engineers to aid in the development of a comprehensive water resources plan for the Potomac River Basin.

These investigations were authorized by the Corps of Engineers in a letter dated June 6, 1958, accepting and approving the plan of study as outlined by the Public Health Service in correspondence dated December 3, 1957. The report also complies with responsibilities of the Public Health Service to assist the Corps of Engineers in implementing water supply programs as authorized in the Memorandum of Agreement entered into on November 4, 1958, under the Water Supply Act of 1958 (Title III, P.L. 500, 85th Congress), and for determining requirements and benefits relating to water quality control by flow regulation as provided in the Federal Water Pollution Control Act Amendments of 1961 (P.L. 87-88).

This part identifies water use areas within the Potomac Basin (excepting the North Branch) where projected water requirements indicate that development of additional sources of water will be needed to meet future demands and where multiple-purpose reservoir projects could be utilized to meet these requirements. Stream reaches requiring additional flow to maintain quality objectives during low flow periods are also identified and rates of supplemental flow are given where satisfaction of these requirements may be applicable to inclusion in specific reservoir projects. Benefits are assigned to various reservoir projects based on costs involved in providing alternate means for satisfying water supply and quality control requirements in the absence of the projects.

SUMMARY

Stream reach areas that will receive benefits from major reservoir projects considered for the Potomac River Basin (excluding the North Branch) are shown below with the annual benefits accruing in 1985 and 2010.

Stream reach areas that cannot be served directly from major reservoirs but have the possibility of installing pipelines to benefit from stored water are given in Table 97.

Areas that have no possibility of receiving benefits from stored water in major reservoirs considered are shown in Table 98.

Stream Reach	Water Use	Average Annual Benefits 1985	2010
Conococheague Creek Chambersburg, Pa.	Water Supply	$ 52,000	$171,000
	Quality Control	471,000	575,000
	Cooling	13,000	22,000
Conococheague Creek Greencastle, Pa.	Water Supply	-	48,000
	Quality Control	283,000	1,097,000
	Cooling	7,000	20,000
West Branch Conococheague Creek Mercersburg, Pa.	Quality Control	258,000	384,000
Conococheague Creek Main Stem Below Confluence of West Branch	Quality Control	219,000	1,065,000
Opequon Creek Winchester, Va.	Water Supply	-	62,000
	Quality Control	591,000	598,000
Middle River, Shenandoah Staunton-Verona, Va.	Water Supply	-	28,000
	Quality Control	85,000	158,000

Stream Reach	Water Use	Average Annual Benefit 1985	2010
		$	$
South River, Shenandoah Waynesboro, Va.	Quality Control	365,000	446,000
South Fork, Shenandoah Elkton, Va.	Quality Control	846,000	1,251,000
South Fork, Shenandoah Mouth of Hawksbill Creek	Quality Control	357,000	974,000
South Fork, Shenandoah Front Royal, Va.	Quality Control	319,000	979,000
Shenandoah Riverton, Va.	Quality Control	103,000	399,000
	Cooling	-	189,000
North Fork Shenandoah River Broadway, Timberville, New Market, Va.	Water Supply	-	18,000
	Quality Control	794,000	999,000
	Cooling	4,000	20,000
North Fork Shenandoah River Mt. Jackson, Edinburgh, Va.	Quality Control	281,000	473,000
North Fork Shenandoah River Woodstock, Strasburg, Va.	Quality Control	30,000	122,000
Shenandoah River Millville-Charlestown, W. Va.	Quality Control	-	329,000
Monocacy River Frederick, Md.	Water Supply	-	172,000
	Quality Control	419,000	1,056,000
Potomac River Dickerson, Md.	Cooling	527,000	1,339,000
Potomac River Great Falls and Downstream	Water Supply	263,000	2,960,000
	Quality Control	10,925,000	11,953,000

STUDY PROCEDURES

Water supply benefit computations are based on the premise that where waters stored in multi-purpose projects could be utilized more economically or would provide greater dependability in quantity and quality than if developed at other sites or by other means, the benefit applicable to the project would be equivalent to the cost of developing the most likely and economical alternate supply commensurate with quantity and quality requirements.

Whereas future municipal and industrial water supply requirements enumerated in Parts V, VI, and VII were determined from the necessity of developing additional sources of municipal and industrial water, conclusions as to choice or availability of sources in lieu of utilizing multiple-purpose storage are already made apparent, i.e., dependable sources in existence and presently developed have been taken into account and where future demands exceed these, consideration is given to the utilization and multiple-purpose storage with benefits applied accordingly.

Various aspects concerning the quality control program for the Potomac River Basin have been described in Parts V, VI, and VII of the Potomac River Basin Study Report. The degrees of conventional municipal and industrial waste treatment normally considered adequate or economically and practicably feasible with provision for improvements in treatment practices for the future are described in these parts of the report. Stream quality objectives are also described in the aforementioned parts of the report as well as means for controlling bacteria pollution and effects of residual waste and runoff material--control of the former to be by effluent disinfection and the latter by flow regulation.

Diversion of wastes to larger bodies of receiving water are described in this part, either as an alternate to flow regulation or as part of the control plan where storage potentials are not sufficient to provide the required dilution flow. Transbasin diversions are also described where these would be necessary and justifiable in meeting requirements for water supply and quality control in adjacent sub-basins.

Where flow regulation is an integral part of the overall water quality control program and major storage projects are necessarily involved in providing this control, benefits assignable to such projects for this purpose are considered to be equivalent to costs involved in constructing single-purpose alternate impoundments capable of providing similar dilution, or as mentioned above, equivalent to costs involved in diverting wastes to larger bodies of water providing that quality objectives were not violated in the larger body of water as a result of such diversions.

Where industrial or thermo-electric cooling requirements would exceed minimum natural stream flows but would utilize augmenting water, a benefit is added to the supplemental flow benefits and is equivalent to the cost of alternate cooling methods. Evaporation losses accruing from such use are considered replaceable at reimbursement values equivalent to single-purpose alternate water supply costs.

All benefits are computed on an annual basis and represent December 1961 construction costs (E.N.R. Construction Cost Index 855; 1913-100). Because a basin development plan has not been adopted or a construction schedule formulated, all benefits are necessarily computed on the basis of present, 1985 and 2010 requirements. When a final plan is adopted, it is suggested that annual benefits be read from the graphs in accordance with approximate time of need and that these benefits be allocated to specific projects as development schedules dictate.

BENEFIT COMPUTATION

There are 35 population areas or stream reaches enumerated in Parts V, VI, and VII that were evaluated for need of new water supply sources and flow regulation as a supplement to waste treatment for control of stream quality. The evaluation covered a 50-year projection. These population areas cover the entire Potomac Basin, except for the North Branch of the Potomac where the benefits are covered in Part IV of the Report.

Eleven of the 35 show a need for development of municipal water supply, 4 have a need for industrial water supply development,and 25 show a need for quality control. Five areas will receive an added benefit from increased flows for cooling purposes. However, in not all instances is it possible, because of site limitations, to provide augmenting flow to meet these needs. Where the future requirements can be met by storage reservoirs, a benefit will accrue from flow regulation.

Where sufficient augmenting flow cannot be developed, a plan for diverting either the quality control flows to areas of needs or waste effluent to larger bodies of water is indicated.

The need areas are separated into three groupings: (1) the areas whose needs can be met with flow regulation from major reservoirs, (2) the areas whose needs can be partially met by diverting flows from the major reservoirs or by alternate means, and (3) the areas whose needs cannot be served by flow regulation from major reservoir sites and must develop alternate means of meeting their requirements.

Table 96 lists the areas of the first group where future demand will exceed the natural stream flow and identifies the reservoir project that could be utilized to meet these needs by flow regulation. In each case a benefit from flow regulation will accrue to the reservoir for either water supply or quality control, or both. In some cases where the need for cooling water is apparent an additional benefit will accrue if the supplemental water supplied is sufficient to meet the requirement.

In most cases, it is assumed that where a combined need for both water supply and quality control exists, the development will be for the total water needs rather than for quality control or water supply only. Also, in most cases, cost to develop alternate single-purpose storage facilities for augmenting purposes are used as the benefit assignable to major projects.

For identidication purposes the major reservoir sites, names, and locations considered are given below. The numbers preceding the names are those used in this report and are the same as those used by the Corps of Engineers in the November 1961 Information Bulletin on the Potomac River Basin Study. The numbers following the names are those used in earlier Public Health Service reports. North Branch Potomac reservoir sites are included, as storage provided in these reservoirs will add to the downstream flows.

Site No.	Name and Location
1	Stony River, near U. S. 50 Highway Bridge
2	North Branch at Bloomington
3	Savage River above existing reservoir
4	South Branch above Petersburg, West Virginia (#7 Part III) (#4 Part VI)
5	Conococheague Creek Valley - West Branch (#2 Part III)
6	Conococheague Creek Valley - Back Creek (#6A Part VI)
7	Conococheague Creek Valley - Main Stem (#6 Part III) (#6 Part VI)
8	Opequon Creek near Winchester, Virginia (#4 Part III) (#7 Part VI)
9	North Fork Shenandoah at Brocks Gap (#16 Part V)
10	Middle River below Staunton, Virginia (#32 Part V)
11	Monocacy River above Frederick, Maryland (#11A Part VI)
12	Main Stem Potomac at River Bend
12a	Main Stem Potomac near Seneca Creek (Alternate site for River Bend site)
13	Shenandoah River near Charles Town, West Virginia (#4 Part V)
14	Back Creek, West Virginia, and Virginia (#3 Part III) (22 Part VI)
15	Licking Creek, Pennsylvania (#1 Part III) (#21 Part VI)
16	Tonoloway Creek, Maryland, and Pennsylvania (#1 Part III) (#20 Part VI)

Table 96

Group I Need Areas Whose Requirements Can Be Met By
Flow Regulation from Major Reservoirs

Location	Type Requirement	Served By Major Reservoir
Conococheague Creek Chambersburg, Pa.	Water Supply Quality Control Cooling	Site #7
Conococheague Creek Greencastle, Pa.	Water Supply Quality Control Cooling	Sites #6, #7
West Branch Conococheague Creek Mercersburg, Pa.	Quality Control	Site #5
Conococheague Creek Main Stem Below Confluence with West Branch	Quality Control	Sites #5, #6, #7
Opequon Creek Winchester, Va.	Water Supply Quality Control	Site #8
Middle River Shenandoah Staunton-Verona, Va.	Water Supply Quality Control	Site #10
South Fork Shenandoah Elkton, Va.	Quality Control	Site #10
South Fork Shenandoah Below Mouth of Hawksbill Creek	Quality Control	Site #10
Shenandoah River Front Royal	Quality Control	Sites #10, #20
Shenandoah River Riverton	Quality Control Cooling	Sites #9, #10, #20
North Fork Shenandoah Broadway, Timberville, New Market, Va.	Water Supply Quality Control Cooling	Site #9
North Fork Shenandoah Mt. Jackson, Edinburg, Va.	Quality Control	Site #9

Table 96 (Continued)

Group I Need Areas Whose Requirements Can Be Met By
Flow Regulation from Major Reservoirs

Location	Type Requirement	Served By Major Reservoir
North Fork Shenandoah Woodstock, Strasburg, Va.	Quality Control	Site #9
Shenandoah River Millville-Charlestown, W. Va.	Quality Control	Sites #9, #13 $10, #20
Monocacy River Frederick, Maryland	Water Supply Quality Control	Site #11
Potomac River Dickerson, Maryland	Cooling	Sites #1 - 23
Potomac River Great Falls and Downstream	Water Supply Quality Control	Sites #1 - 23

Site No.	Name and Location
17	Sideling Hill Creek, Maryland (#1 Part III) (#18 Part VI)
18	Town Creek, Maryland (#4 Part III) (#16 Part VI)
19	South Branch near Springfield, West Virginia (#10A Part III) (#14 Part VI)
20	South Fork Shenandoah above Front Royal (#45 Part V)
21	Little Cacapon River, West Virginia (#1 Part VII) (#17 Part VI)
22	Cacapon River, West Virginia (#1 Part III) (#19 Part VI)
23	Patterson Creek, West Virginia (#4 Part III)

Benefits are computed on the cost of single-purpose alternates to supply requirements for the least cost at any time and represent benefit potential for any need area at any time.

The costs of the alternate sources were developed by the Baltimore District, Corps of Engineers. These figures reflect the average annual cost to develop the most likely and economical alternate sources to supply the amount of supplemental water needed for the indicated area. They are based on present prices and non-Federal finance rates of 4 per cent for water supply and quality control, and 5 per cent for cooling water.

The general procedure for computing benefits at any need area is as follows:

(a) The total annual low flow benefit at any needs center at any time is the average annual cost per cfs to develop the required supplemental flow times the flow furnished or flow required, whichever is less.

(b) The annual water supply benefit at any needs center at any time is the same percentage of the total benefit that water supply requirement is to the total requirement.

(c) The annual quality control benefit at any needs center at any time is the total benefit minus the water supply benefit.

(d) To apportion the benefits among several reservoirs, use the supplemental flow supplied by each reservoir divided by the total supplemental flow required times the total benefit. Under this method, the benefit is proportional to each reservoir furnishing flow to the needs center in accordance to respective flows from each.

In those instances where cooling water uses would exceed natural stream flow and thereby utilize the cooling properties of the supplemental quality control flow, an added benefit assignable to the source of augmenting flow is established. The benefits

assignable to augmentation would be equivalent to costs necessary in accomplishing the same coding efficiency by alternate means. Where cooling water requirements exceed the volume of water available the user may elect to increase the supply by augmentation methods, or install cooling towers or ponds and recirculate a major portion of available waters. The loss of water resulting from cooling tower operation is described in Part IV Report on the North Branch Potomac.

The value of augmented river flow based on cooling tower operation to accomplish the required cooling capacity includes capital and operation costs for cooling towers, and costs to replace the consumptive amount of make-up water. The latter represents the difference between cooling tower and river operation.

No attempt is made to evaluate the benefits derived from improved operating efficiency due to temperature reduction in the stream, although they may be considerable depending on location and operating schedules of the reservoirs.

Assuming that cooling water requirements can be met with the augmented water without detriment to the stream from heat pollution, the benefits will be equal to the value of cooling towers required to perform the same operation.

One cubic foot per second of once-through cooling water is required for each 1000 kilowatts of power produced.

The average installed cost of cooling towers is approximately \$8 per kilowatt. The average life of cooling towers is about 11 years, and annual operation and maintenance costs amount to about 4 per cent of the capital cost, or about \$.32 per kilowatt. At an interest rate of 5 per cent, the total cost of cooling towers is summarized as follows:

Installed Cost	\$ .727 per kw per year
Interest at 5%	\$ .40 per kw per year
Operation and Maintenance	\$ .32 per kw per year
Total	\$1.447 per kw per year

At one (1) cfs once-through cooling water for each 1000 kilowatts, the value of cooling water is 1000 x 1.447 or \$1,447 per year per cfs (say \$1,450 per year per cfs).

In addition to amortization and operation and maintenance costs for cooling towers, an additional consumptive use of water over river operation would result. The amount of water used in a closed system is 5 per cent of that used for a once-through operation, or about .05 cfs make-up water for each cfs of once-through flow. Evaporative loss is approximately 50 per cent or .025 cfs make-up water for each cfs needed.

The value of make-up water is equivalent to the cost of augmented water for the particular area. Cooling benefits are summarized for each need area in the following manner:

cfs augmented flow needed X $1,450	=	$/yr
cfs needed X .025 X $/cfs	=	$/yr
Total value of cooling flow	=	$/yr

SUMMARY OF BENEFITS BY STREAM REACHES

The following section deals separately with each stream reach.

Conococheague Creek
Chambersburg, Pennsylvania

Present and Expected Future Requirements (Part VI):

			Present	1985	2010
Municipal Water Supply	Avg.	(cfs)	4.2	11.2	24.7
	Max.	(cfs)	6.3	15.2	31.8
Quality Control		(cfs)	40.0	63.0	82.0
Cooling		(cfs)	[3.9]	[7.7]	[13.1]

Alternate Cost - Total Water Requirements

		Present	1985	2010
Total Water Requirements	(cfs)	44.2	74.2	106.7
Design Flow	(cfs)	12.0	12.0	12.0
Supplemental Flow Required	(cfs)	32.2	62.2	94.7
Annual Cost of Alternates	($/yr)	270,000	523,000	746,000

Benefits:

These costs will accrue as a benefit for water supply and quality control to the major site on Main Stem Conococheague Creek (#7).

The costs are apportioned as benefits as follows:

		Present	1985	2010
Municipal Water Supply	($/yr)	0	52 000	171,000
Quality Control	($/yr)	270,000	471,000	575,000

In addition to these benefits, a benefit for cooling water is obtained:

		Present	1985	2010
Cooling Requirement	(cfs)	3.9	7.7	13.1
Design Flow	(cfs)	6.0	6.0	6.0
Water Supply Requirement	(cfs)	4.2	11.2	24.7
Portion Design Flow for Cooling	(cfs)	1.8	none	none
Additional Cooling Requirement	(cfs)	2.1	7.7	13.1
Make-up Water Requirement	(cfs)	.1	.2	.3
Equivalent Annual Cost	($/yr)	4,000	13,000	22,000

Figure 110 shows the benefits that will accrue to major reservoirs that will service the needs.

Chambersburg is now getting its water supply from impoundments on Hoosier Run and Birch Run of Conococheague Creek. Future development would probably come from the alternate sites if the Main Stem Conococheague Creek site was not constructed. To draw its water supply from the main stem site, Chambersburg wastes must be piped below the dam. Quality characteristics of the water in the reservoir are discussed in Part VI of the Potomac Report.

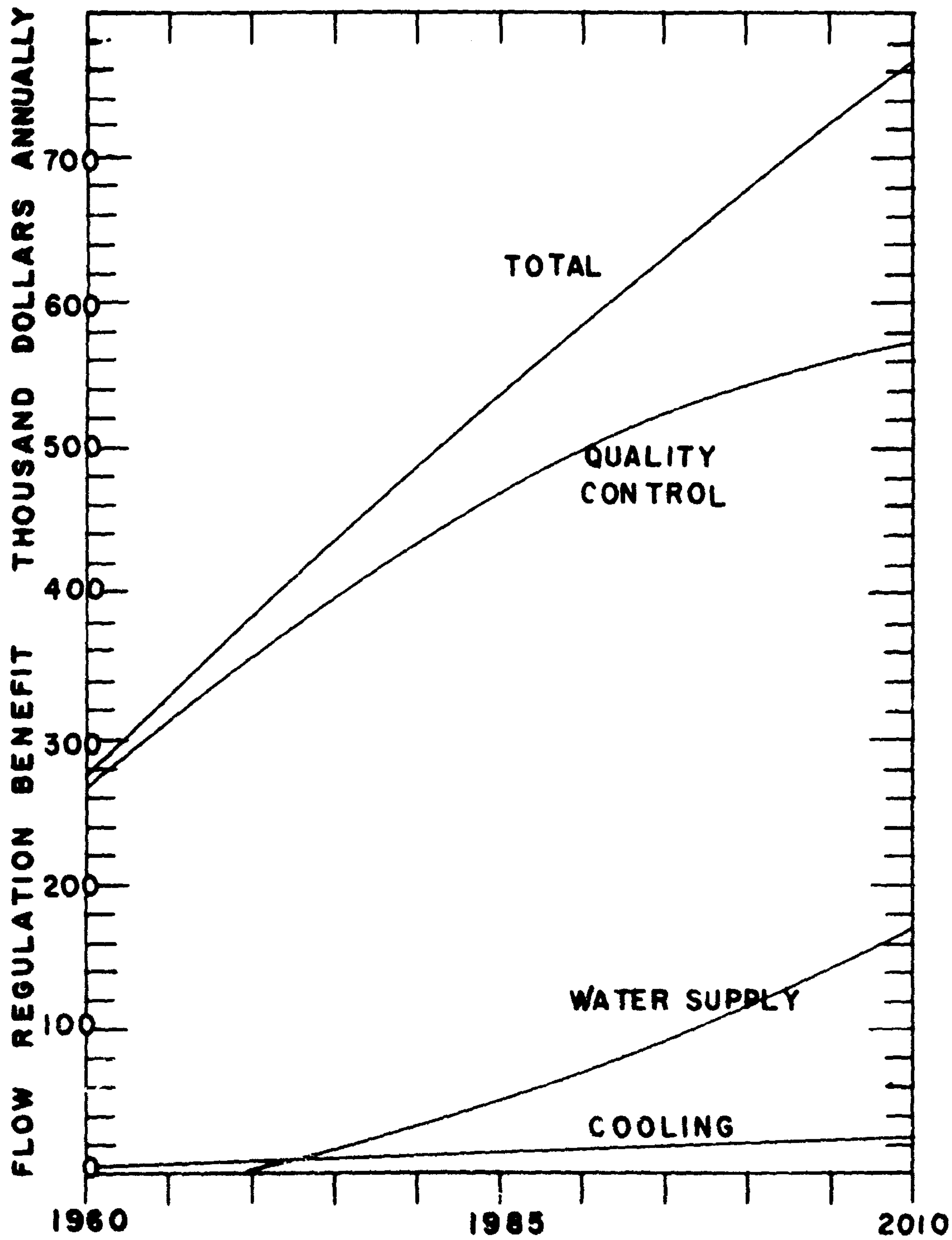
Conococheague Creek
Greencastle, Pennsylvania

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Municipal Water Supply	Max. (cfs)	1.6	3.9	8.9
Industrial Water Supply	(cfs)	3.6	9.0	14.6
Quality Control	(cfs)	41	88	186
Cooling	(cfs)	-	[7.7]	[12.3]

Alternate Cost - Total Water Requirements

		Present	1985	2010
Total Need	(cfs)	46	100.9	209.0
Design Flow	(cfs)	30	30	30
Supplemental Flow Required	(cfs)	16	70.9	179.0
Annual Cost of Alternates	($)	40,000	283,000	1,145,000



CONOCOCHEAGUE CREEK
CHAMBERSBURG, PA.

FIGURE 110

Benefits:

The costs accruing as a benefit to the Main Stem Conococheague and Back Creek reservoir are as follows:

		Present	1985	2010
Industrial Water Supply	($/yr)	-	-	48,000
Quality Control	($/yr)	40,000	283,000	1,097,000

In addition to the above, an added benefit for cooling water will accrue.

		Present	1985	2010
Cooling Water Required	(cfs)	-	[7.7]	[12.3]
Portion Design Flow for Cooling	(cfs)	9.8	2.1	none
Supplemental Cooling Required	(cfs)	none	4.6	12.3
Make-up Water Required	(cfs)	-	.2	.3
Total Annual Cooling Cost	($)	-	7,000	20,000

The annual benefits accruing for this area are shown in Figure 111.

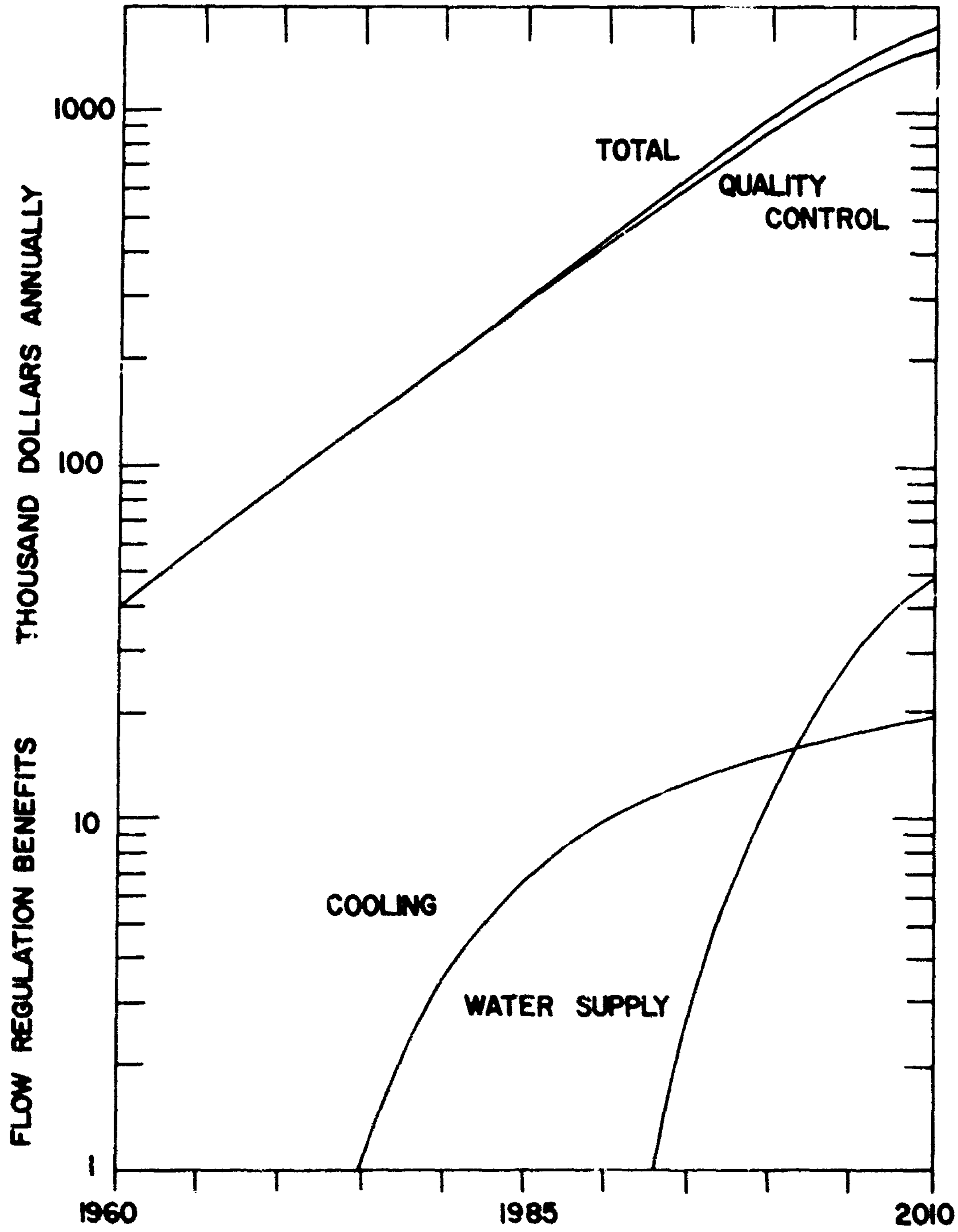
If Chambersburg wastes are diverted below the dam, this area could draw its water supply from the reservoir. The water quality in this reach is discussed in Parts III and VI of the report.

The benefits will accrue to the major reservoir on the Main Stem Conococheague and the Back Creek, Conococheague reservoir in proportion to their contributing flows to this area.

West Branch Conococheague Creek
Mercersburg, Pennsylvania

Present and Projected Future Requirements (Part VI):

			Present	1985	2010
Municipal Water Supply	Max.	(cfs)	0.6	1.3	2.7
Industrial Water Supply		(cfs)	0.5	1.3	2.3
Quality Control		(cfs)	25.0	32.0	39.0



CONOCOCHEAGUE CREEK
GREENCASTLE, PA.

FIGURE 111

Alternate Cost - Total Water Needs

		Present	1985	2010
Total Water Requirements	(cfs)	26.1	34.6	44.0
Design Flow	(cfs)	16.0	16.0	16.0
Supplemental Flow Required	(cfs)	10.1	18.6	28.0
Total Annual Cost of Alternates	($)	133,000	258,000	384,000

Water supply needs can be met from natural flow so that all supplemental flow is required for quality control purposes, and the entire annual benefits would accrue to the major reservoir considered on West Branch Conococheague.

Water quality aspects of this area are discussed on page 152 of Part III.

Figure 112 shows the annual benefits to be derived from flow regulation for this area.

Conococheague Creek
Below Confluence of Main Stem and West Branch

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Quality Control Flow Required	(cfs)	56	107	220
Design Flow	(cfs)	51	51	51
Supplemental Flow Required	(cfs)	5	56	169
Total Annual Cost of Alternates	($/yr)	13,000	219,000	1,065,000

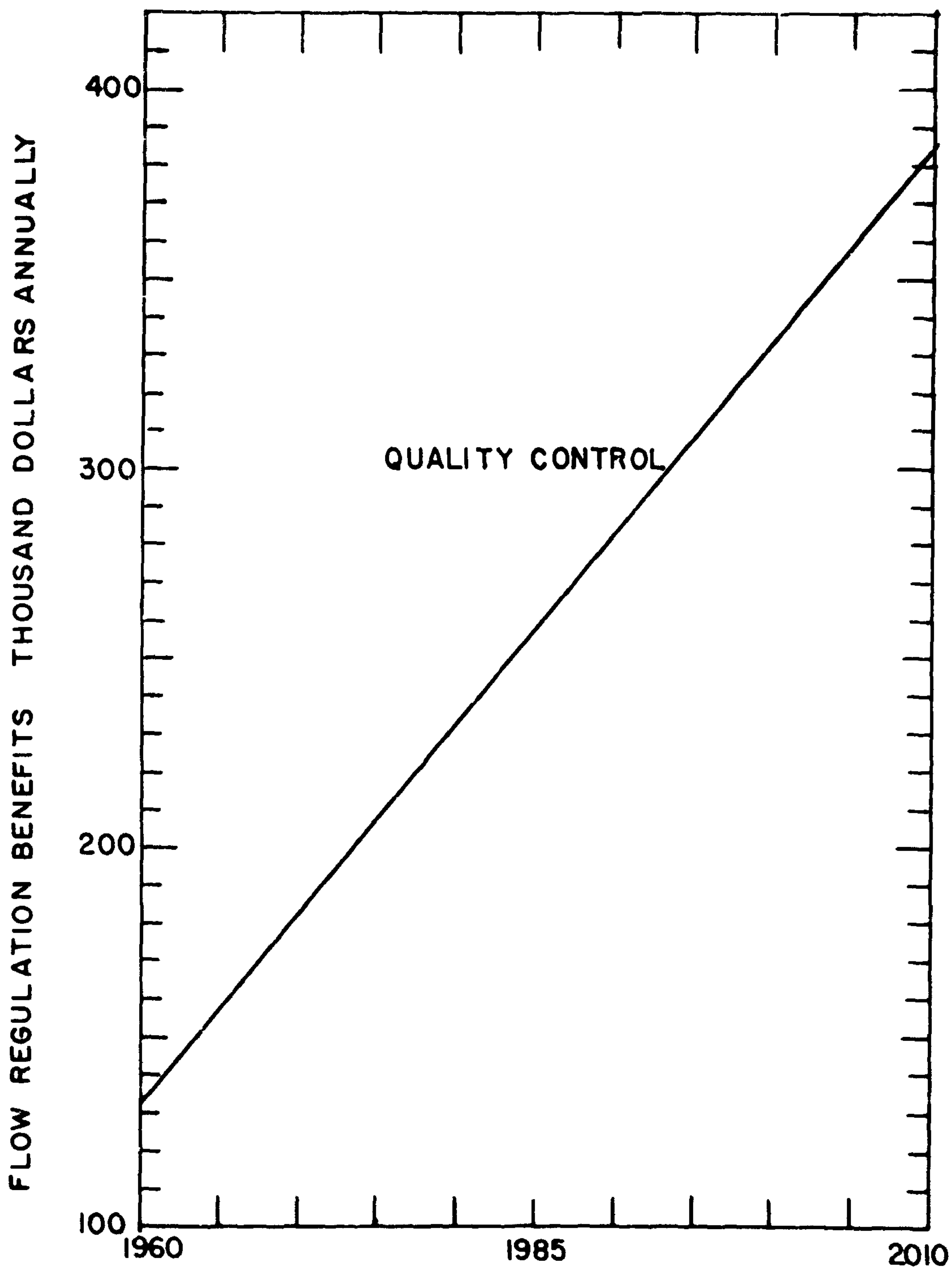
The above amounts would accrue as benefits to the three reservoirs considered for Conococheague Creek in proportion to their contributing flows.

Figure 113 shows the flow regulation benefits accruing for major reservoirs considered.

Opequon Creek
Winchester, Virginia

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Municipal Water Supply	(cfs)	6.0	14.1	21.9
Quality Control	(cfs)	31.0	45.0	67.0



WEST BRANCH CONOCOCHEAGUE

MERCERSBURG, PA.

FIGURE 112

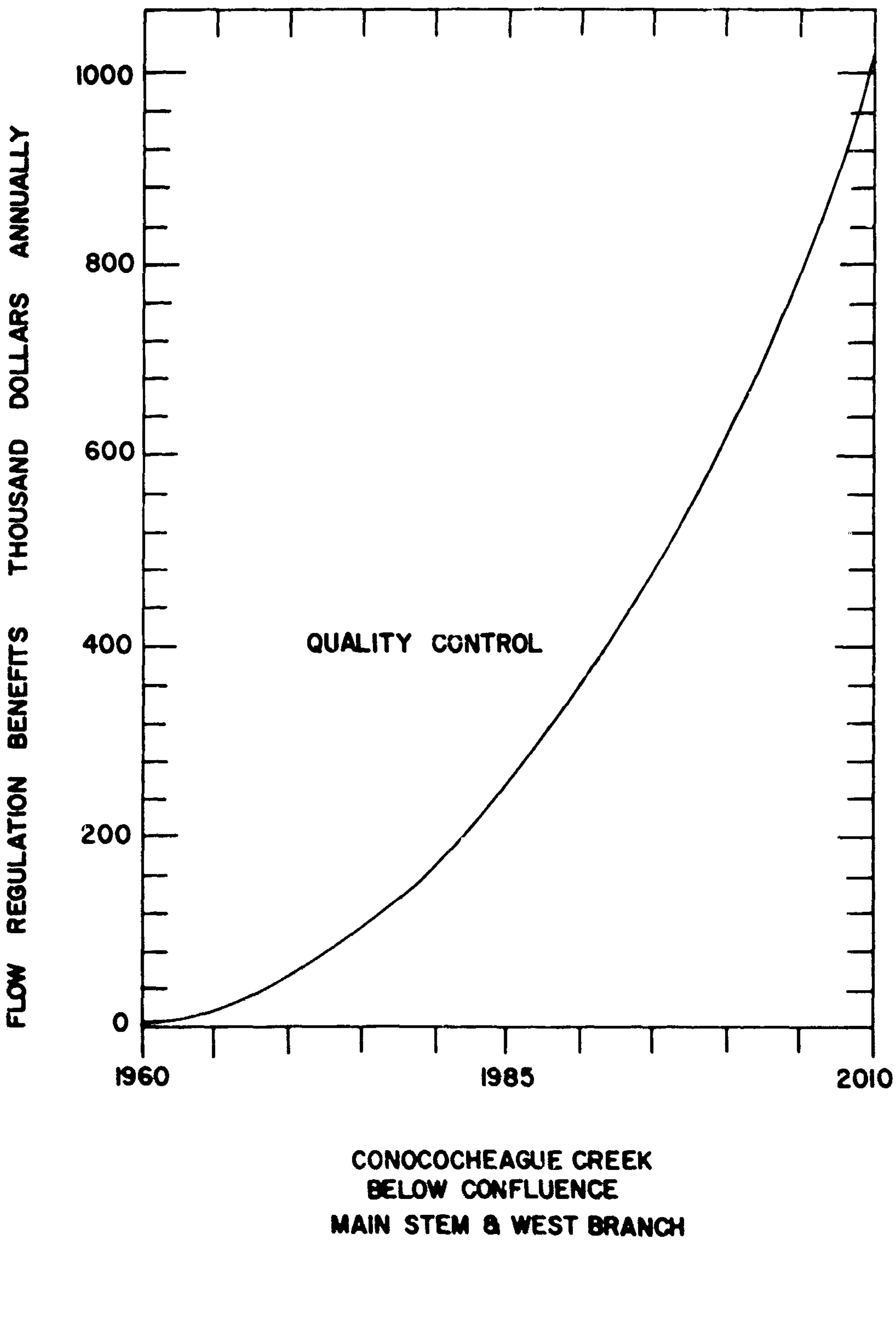

FLOW REGULATION BENEFITS THOUSAND DOLLARS ANNUALLY
1000
800
600
400
200
0
QUALITY CONTROL
1960
1985
2010
CONOCOCHEAGUE CREEK
BELOW CONFLUENCE
MAIN STEM & WEST BRANCH

FIGURE 113

Winchester, Virginia, presently pipes its water supply from the North Fork of the Shenandoah. The natural flows in the North Fork are sufficient for future needs so no benefit would accrue to any proposed reservoir for water supply in the North Fork. The capacity of the pipeline is limited to about 15 cfs or about 7 cfs short for 2010 needs. At the time capacity is exceeded (approximately 1990), it is possible that needed water would come from Opequon Creek if the Opequon reservoir is there. A benefit would then accrue to this reservoir for water supply.

With part of the water supply needs taken care of by the North Fork, Opequon Creek would only supply quality control until the capacity of the pipeline is exceeded.

Alternate Cost - Total Water Needs

		Present	1985	2010
Total Flow Required	(cfs)	31.0	45.0	74
Design Flow	(cfs)	0	0	0
Supplemental Flow Required	(cfs)	31	45	74
Annual Cost	($)	407,000	591,000	651,000

The cost to provide the 7 cfs for water supply in 2010 from Opequon would be $62,000 per year.

The full amount of alternate cost would accrue as a benefit to the major reservoir on Opequon Creek with Winchester waste effluent piped below the dam.

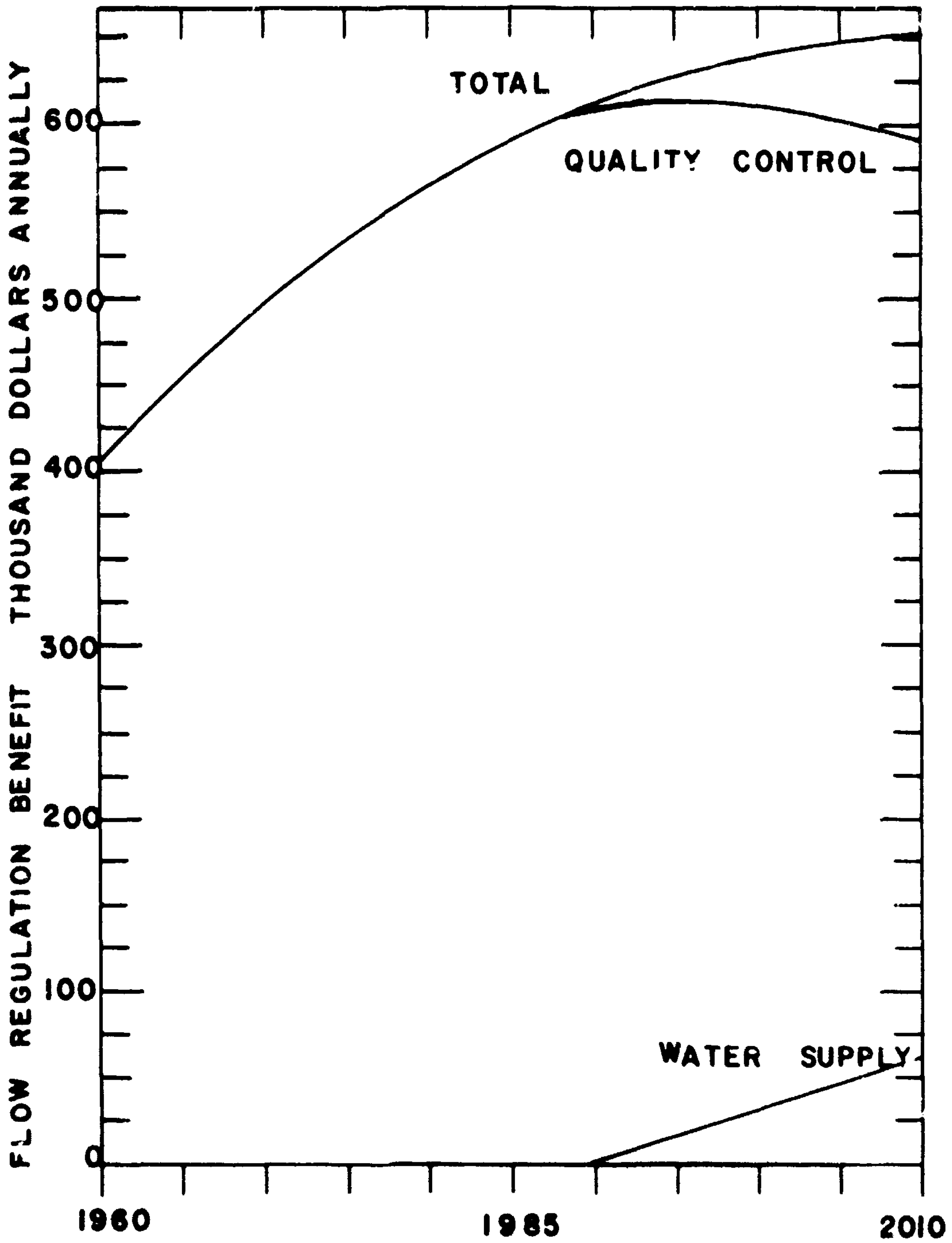
Figure 114 shows the annual benefits that would accrue to this area.

Water quality in relation to this reservoir is discussed in Part VI.

Shenandoah River - Middle River
Staunton - Verona, Virginia

Present and Projected Future Requirements (Part V):

			Present	1985	2010
Municipal Water Supply	Max.	(cfs)	5.7	13.3	26.8
	Avg.	(cfs)	3.8	9.8	21.0
Quality Control		(cfs)	41.0	70.0	85.0



OPEQUON CREEK
WINCHESTER, VA.

FIGURE 114

Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	46.7	83.3	111.8
Design Flow	(cfs)	49	49	49
Supplemental Flow Required	(cfs)	none	34.3	62.8
Annual Cost to Provide Total Supplemental Flow	($)	-	85,000	186,000

Apportionment of Total Cost for Water Supply and Quality Control is as follows:

Water Supply	($/yr)	-	-	28,000
Quality Control	($/yr)	-	85,000	158,000

These amounts would accrue as benefits to the major reservoir site on Middle River for flow regulation.

Figure 115 shows the annual benefits as they would accrue for this area for water supply and quality control.

The needs and present supply methods are discussed in Part V, page 318. Water quality relative to the major reservoir considered for Middle River is discussed on page 531.

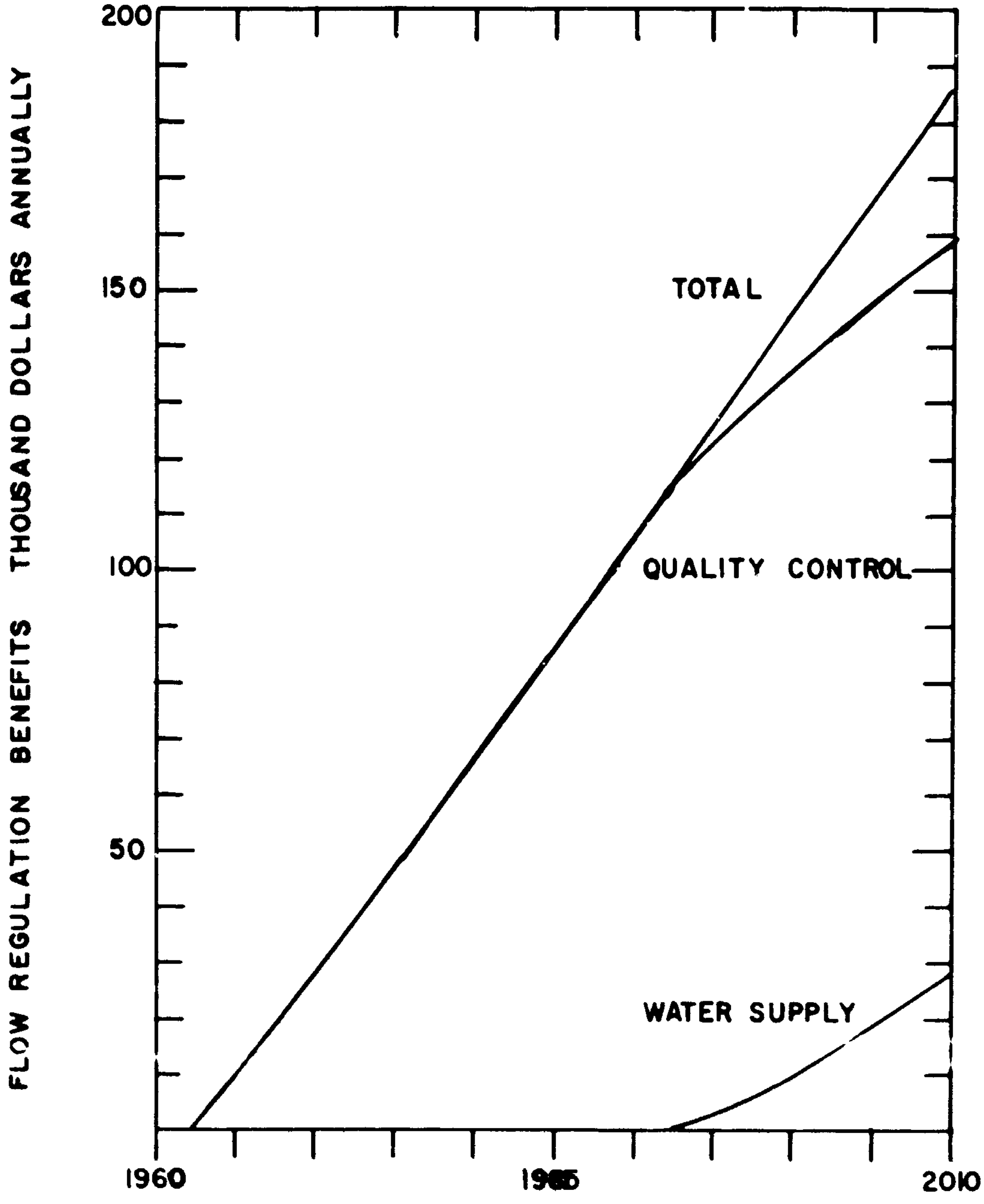
Shenandoah River (South Fork)
Elkton, Virginia

Present and Projected Future Requirements (Part V):

		Present	1985	2010
Municipal Water Supply	Max. (cfs)	1.3	4.3	9.4
Industrial Water Supply	(cfs)	2.0	4.0	6.0
Quality Control	(cfs)	256.0	348.0	425.0
Cooling	(cfs)	[11.9]	[23.7]	[35.7]

Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	259.3	356.3	440.4
Design Flow	(cfs)	184	174	168
Supplemental Flow Required	(cfs)	75.3	182.3	272.4
Annual Cost of Alternates	($)	368,000	846,000	1,251,000



MIDDLE RIVER
STAUNTON VERONA
VA.

FIGURE 115

The minimum stream flows are sufficient to provide for future water supply and cooling needs; therefore, entire cost of alternates would accrue as a benefit for quality control to reservoir #10.

Figure 116 shows the annual benefits that would accrue as needs are met by flow regulation.

Shenandoah River (South Fork)
Below Mouth of Hawksbill Creek

Present and Projected Future Requirements (Part V):

		Present	1985	2010
Water Supply	(cfs)	None	None	None
Quality Control	(cfs)	251	342	415

Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	251	342	415
Design Flow	(cfs)	230	230	225
Supplemental Flow Required	(cfs)	21	112	190
Annual Cost of Alternates	($/yr)	59,000	357,000	974,000

Benefits:

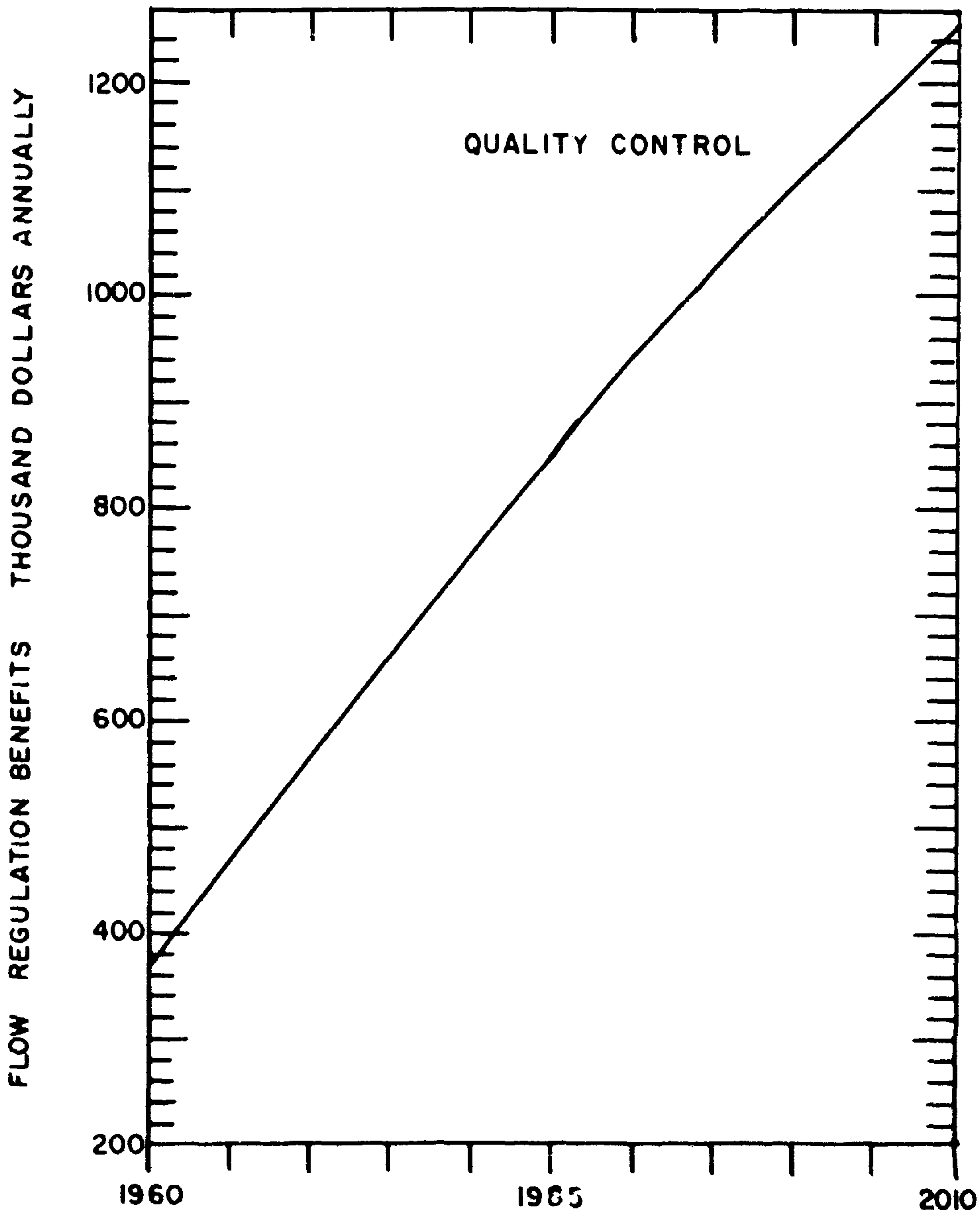
The above costs of providing sufficient flows from alternate sources would accrue as a benefit to reservoir #10 on Middle River for quality control.

Figure 117 shows the annual benefits that would accrue.

Shenandoah River (South Fork)
Front Royal, Virginia

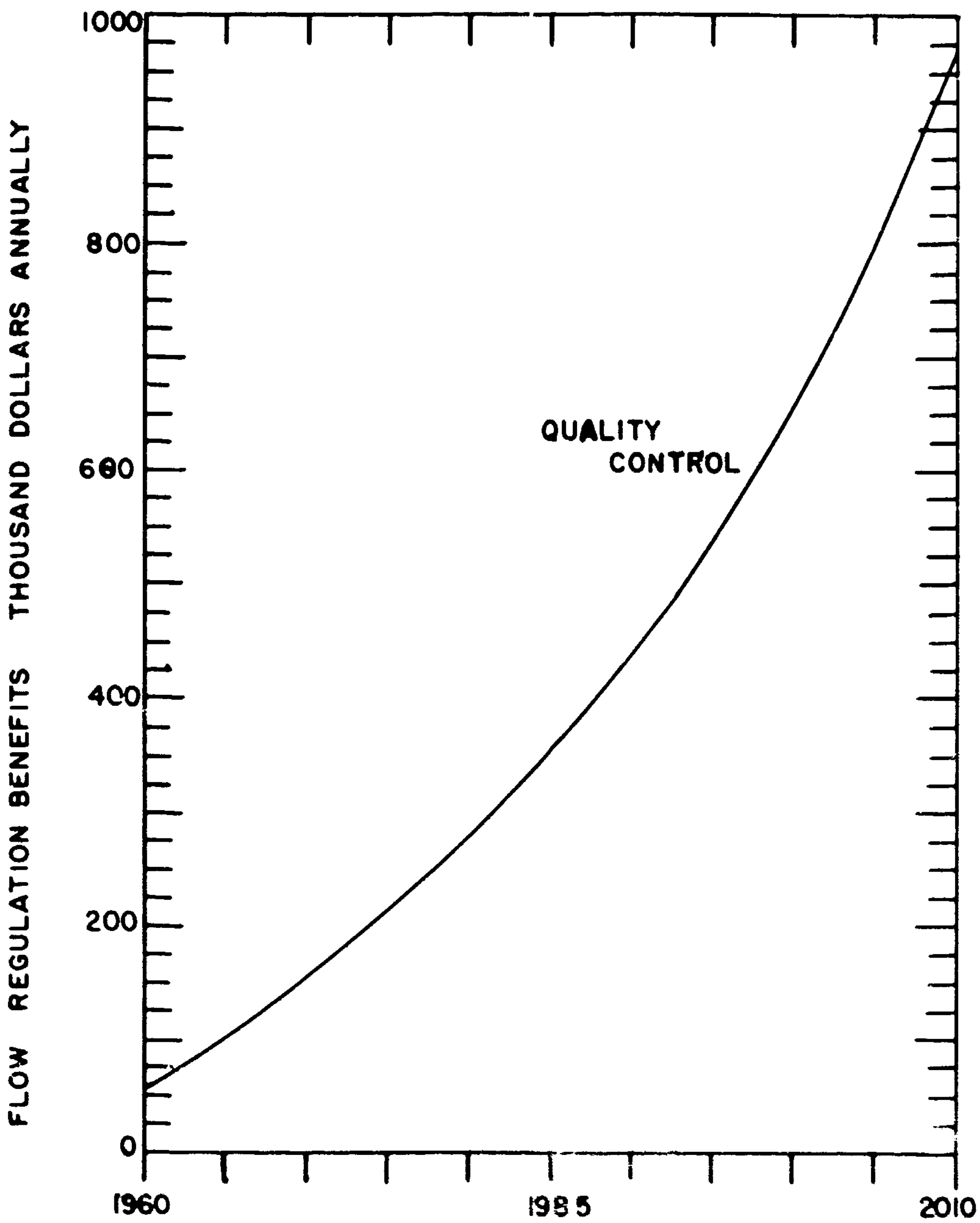
Present and Projected Future Requirements (Part V):

		Present	1985	2010
Municipal Water Supply	(cfs)	2.3	5.4	11.4
Industrial Processing	(cfs)	7.1	16.0	24.7
Quality Control	(cfs)	239	315	383



SOUTH FORK SHENANDOAH
ELKTON, VA.

FIGURE 116



SOUTH FORK SHENANDOAH
BELOW MOUTH OF HAWKSBILL CREEK

FIGURE 117

Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Requirements	(cfs)	248.4	336.4	419.1
Design Flow	(cfs)	255	238	229
Supplemental Flow Requirements	(cfs)	none	98.6	190.1
Total Annual Cost of Alternates	($/yr)	-	319,000	979,000

The stream flows are sufficient to meet all expected requirements for municipal and industrial water supply and the alternate costs would accrue as a benefit for quality control.

Figure 118 shows the annual benefits as they would accrue for the area.

Shenandoah River
Riverton, Virginia

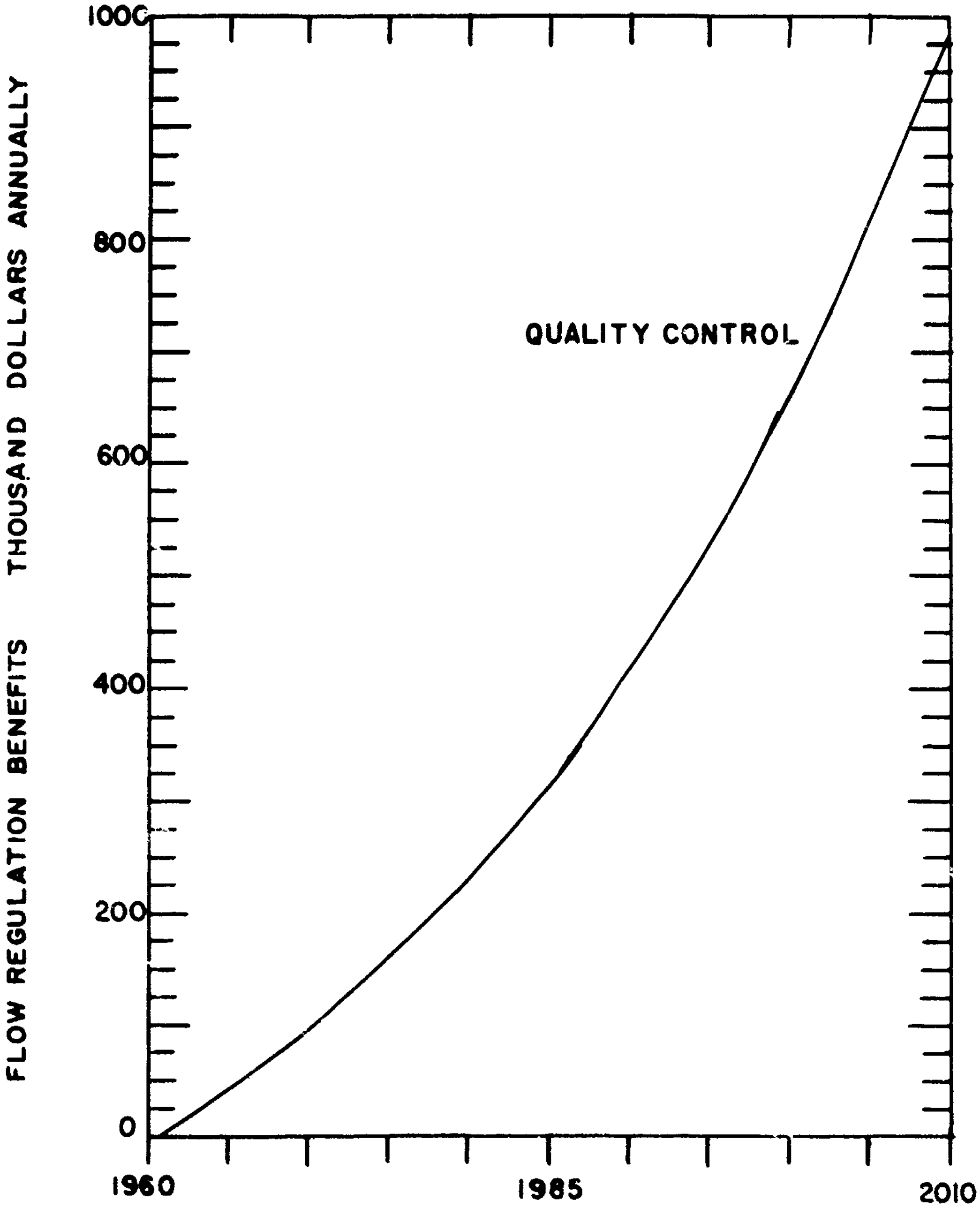
Present and Projected Future Requirements (Part V):

		Present	1985	2010
Municipal Water Supply	(cfs)	.8	2.8	6.0
Quality Control	(cfs)	243	336	412
Cooling	(cfs)	[67]	[191]	[315]

Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	244	339	418
Design Flow	(cfs)	324	306	294
Supplemental Flow Requirements	(cfs)	none	33	124
Total Alternate Cost	($/yr)	-	103,000	399,000

The above alternate costs would accrue as benefits from flow regulation for quality control. Minimum stream flows are sufficient for water supply.



SOUTH FORK SHENANDOAH
FRONT ROYAL, VA.

FIGURE 118

Cooling:

		Present	1985	2010
Requirements	(cfs)	67	190	315
Design Flow	(cfs)	192	192	192
Supplemental Cooling Requirements	(cfs)	none	none	123
Make-up Water Requirements	(cfs)	-	-	3
Total Annual Cooling Cost	($/yr)	-	-	189,000

Figure 119 shows the annual benefits as they would accrue from flow regulations for the area.

Shenandoah River (North Fork)
Broadway, Timberville, New Market, Virginia

Present and Projected Future Requirements (Part V):

		Present	1985	2010
Municipal Water Supply	(cfs)	1.6	5.7	12.5
Industrial Water Supply	(cfs)	1.6	3.6	5.4
Quality Control	(cfs)	102.0	137.0	169.0
Cooling	(cfs)	[2.3]	[8.2]	[13.8]

Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	105.2	146.3	186.9
Design Flow	(cfs)	23	23	23
Supplemental Flow Required	(cfs)	82.2	123.3	163.9
Annual Cost of Alternates	($/yr)	523,000	794,000	1,017,000

These costs are apportioned for water supply and quality control as follows:

		Present	1985	2010
Water Supply	($/yr)	-	-	18,000
Quality Control	($/yr)	523,000	794,000	999,000

		Present	1985	2010
Cooling Requirements	(cfs)	2.3	8.2	13.8
Design Flow	(cfs)	15	15	15
Portion of Design Flow Left For Cooling after Water Supply	(cfs)	11.8	5.7	none
Supplemental Cooling Requirements	(cfs)	none	2.5	13.8
Make-up Water	(cfs)	-	.1	.3
Equivalent Annual Cost	($/yr)	-	4,000	20,000

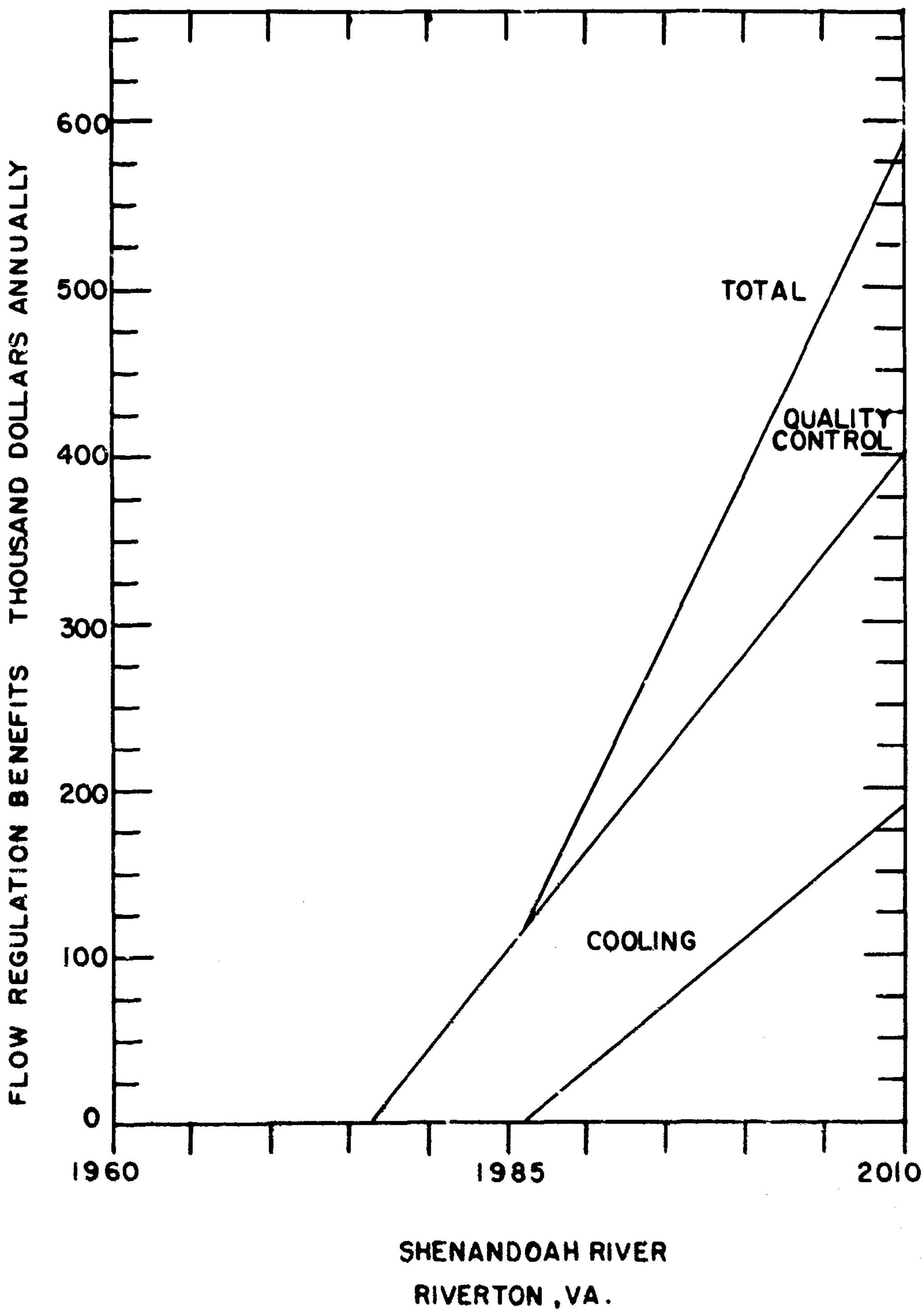

FLOW REGULATION BENEFITS THOUSAND DOLLARS ANNUALLY
600
500
400
300
200
100
0
TOTAL
QUALITY CONTROL
COOLING
1960
1985
2010
SHENANDOAH RIVER
RIVERTON, VA.

FIGURE 119

Figure 120 shows the annual benefits that could accrue for each use for this area. Major reservoir #9 would serve the needs.

Shenandoah River (North Fork)
Mt. Jackson, Edinburgh, Virginia

Present and Projected Future Requirements (Part V):

		Present	1985	2010
Municipal Water Supply	(cfs)	1.7	5.7	12.0
Quality Control	(cfs)	68.0	96.0	118.0

Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	69.7	101.7	130.0
Design Flow	(cfs)	31	25	20
Supplemental Flow Requirements	(cfs)	38.7	76.7	110
Annual Cost of Alternates	($/yr)	110,000	281,000	473,000

Minimum stream flows would meet the expected future demands for water supply; therefore, alternate cost would accrue as a benefit for quality control from flow regulation.

Figure 121 shows the annual benefits that would accrue for this area to major reservoir #9.

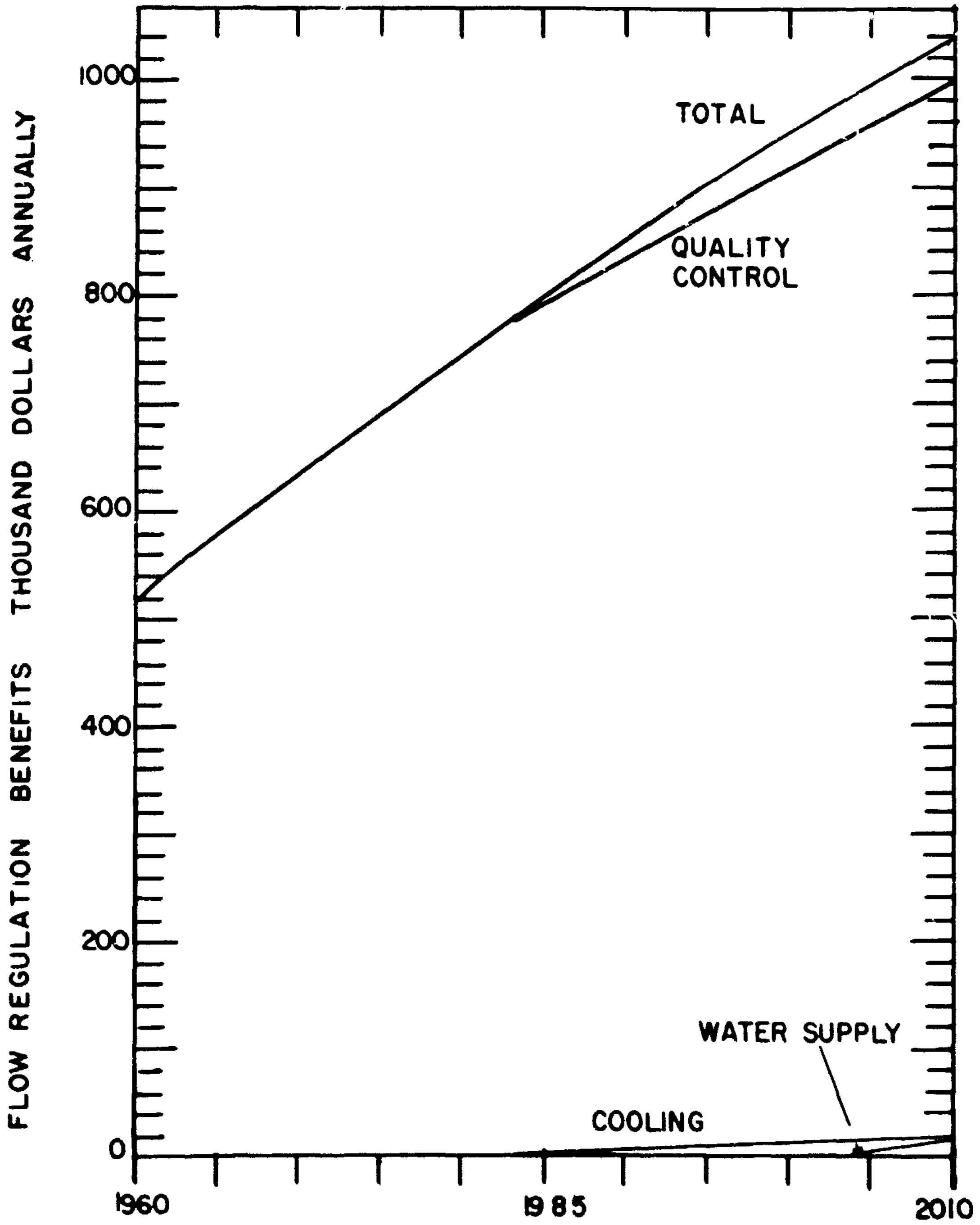
Shenandoah River (North Fork)
Woodstock - Strasburg, Virginia

Present and Projected Future Requirements (Part V):

		Present	1985	2010
Municipal Water Supply	(cfs)	0.9	1.9	3.0
Quality Control	(cfs)	33.5	54.0	68.0

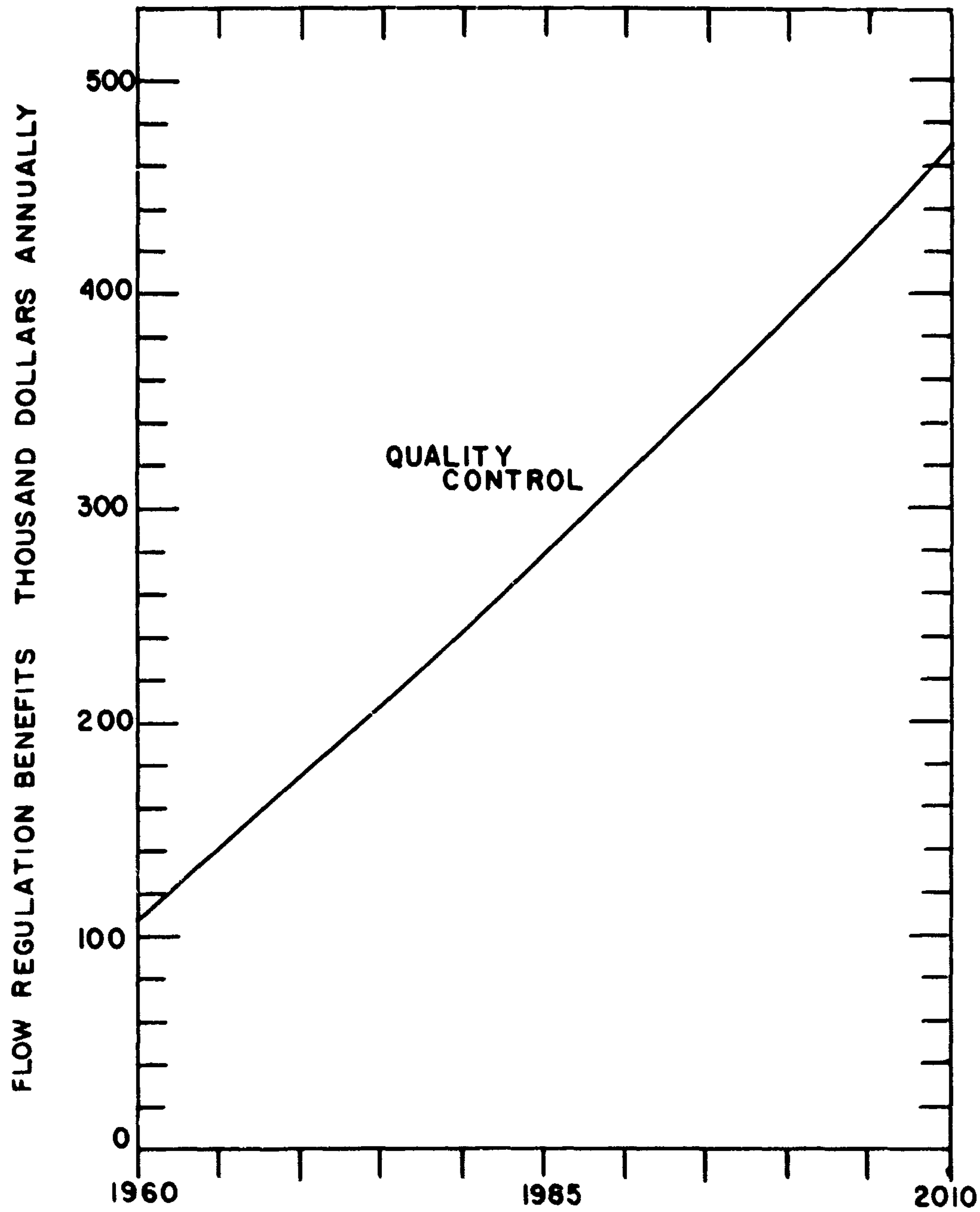
Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	34.4	55.9	71.0
Design Flow	(cfs)	66	45	39
Supplemental Flow Requirements	(cfs)	none	11	32
Annual Cost of Alternates	($/yr)	-	30,000	122,000



NORTH FORK SHENANDOAH
BROADWAY, TIMBERVILLE, NEW MARKET, VA

FIGURE 120



NORTH FORK SHENANDOAH
MT. JACKSON, EDINBURGH, VA.

FIGURE 121

The cost of alternates would accrue as a benefit for quality control since minimum flows in the stream are sufficient to meet expected water supply demands.

Figure 122 shows the benefits that would accrue to major reservoir #9 which could serve these needs.

Shenandoah River
Millville - Charles Town, West Virginia

Present and Projected Future Requirements (Part V):

		Present	1985	2010
Municipal Water Supply	(cfs)	0.9	3.1	6.2
Industrial Water Supply	(cfs)	5.6	12.5	19.4
Quality Control	(cfs)	238.0	329.0	404.0
Cooling	(cfs)	[33.4]	[96]	[157]

Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	244.5	344.6	429.6
Design Flow	(cfs)	367.0	345	322
Supplemental Flow Requirements	(cfs)	none	none	107.6
Annual Cost of Alternates	($/yr)	-	-	329,000

The minimum stream flows are sufficient to meet water supply and cooling needs in the expected future.

Figure 123 shows the benefits that would accrue to reservoirs #9, #13 and #20 in proportion to their contributing flows.

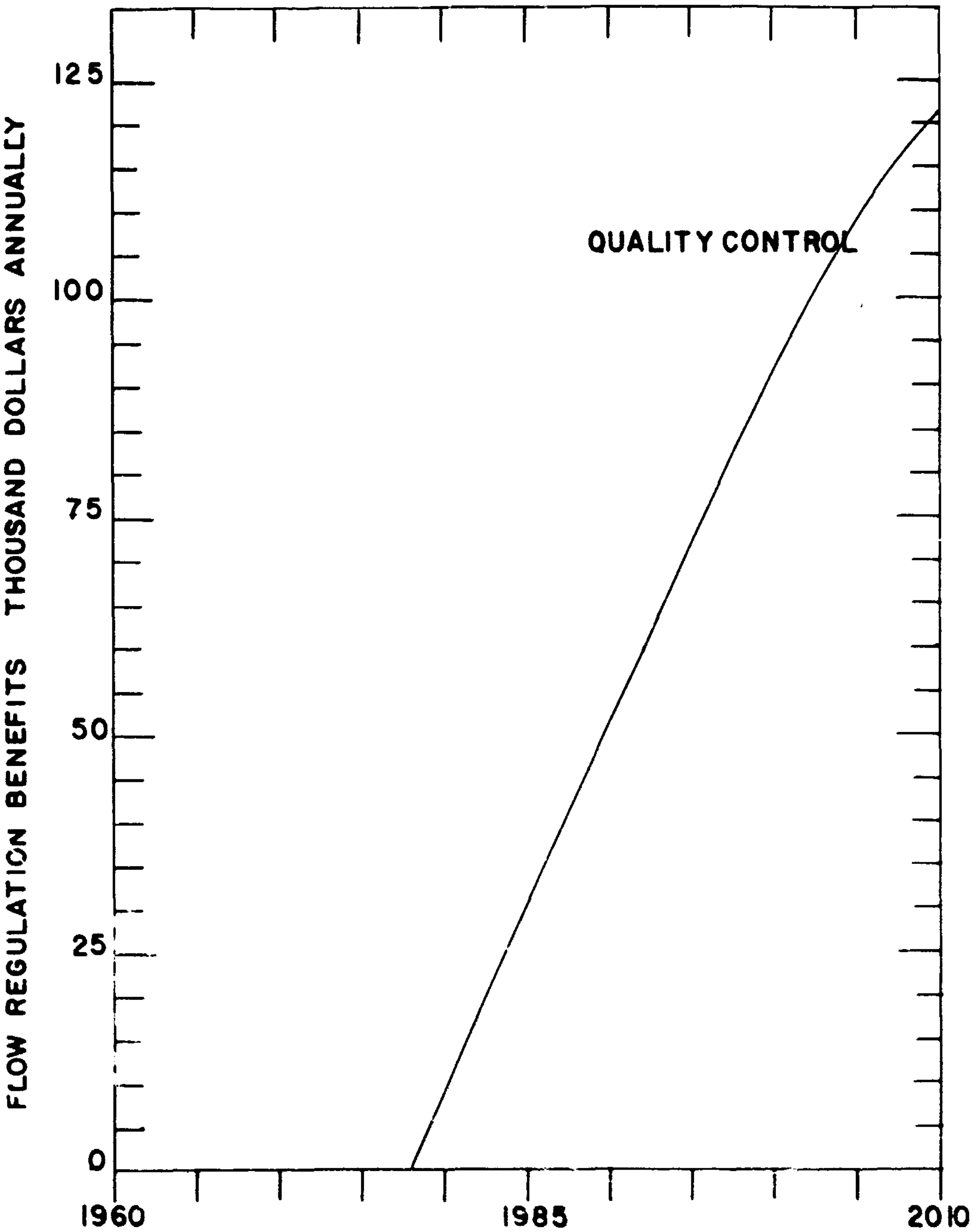
Monocacy River
Frederick, Maryland

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Municipal Water Supply	Max. (cfs)	9.1	22.3	47.0
Quality Control	(cfs)	81.0	134.0	182.0

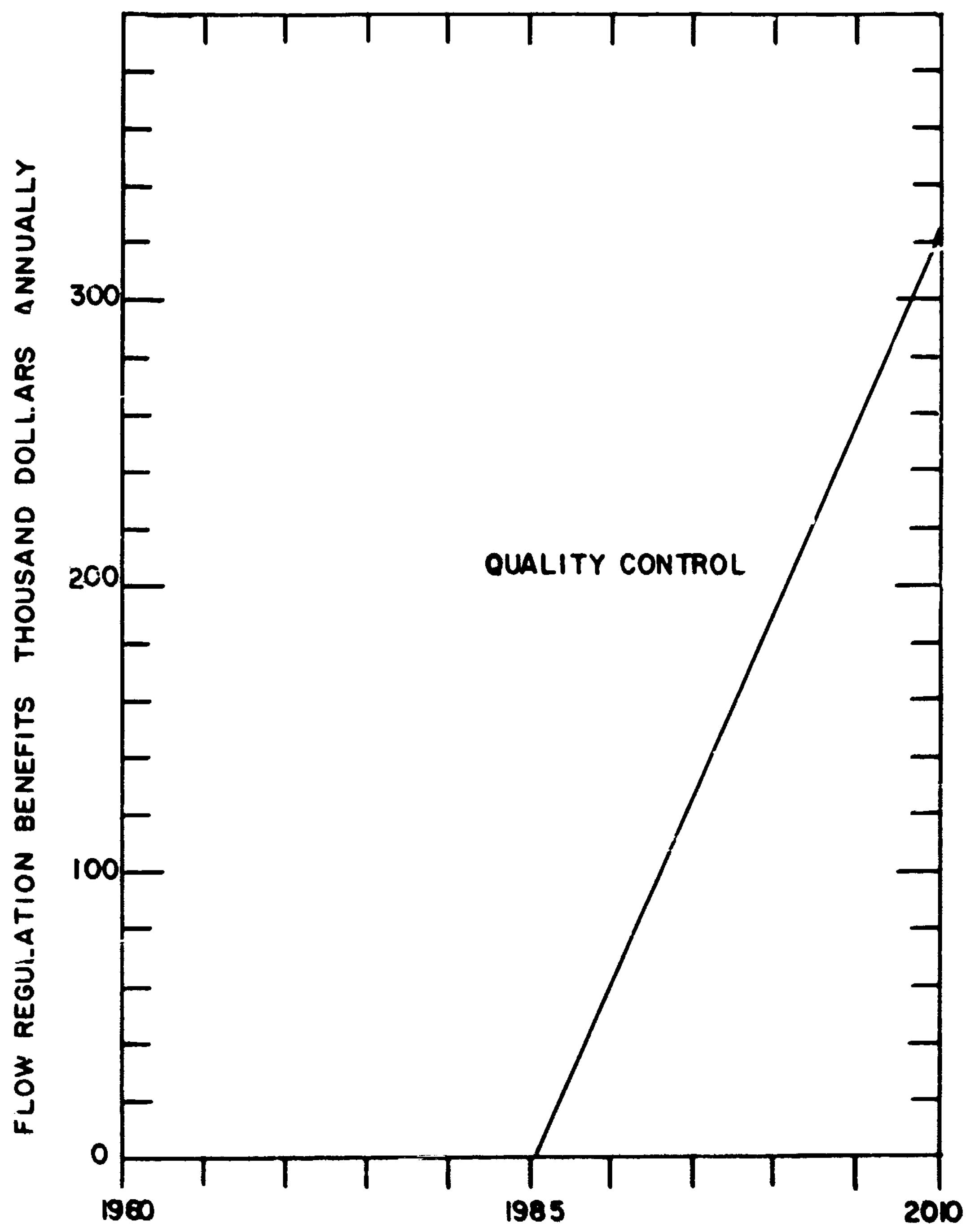
Alternate Cost - Total Needs

		Present	1985	2010
Total Flow Required	(cfs)	90.1	156.3	229
Design Flow	(cfs)	52	48	43
Supplemental Flow Required	(cfs)	38.1	108.3	186
Annual Cost of Alternates	($/yr)	91,000	419,000	1,228,000



NORTH FORK SHENANDOAH
WOODSTOCK, STRASBURG, VA.

FIGURE 122



SHENANDOAH RIVER
MILLVILLE, CHARLESTOWN, W. VA.

FIGURE 123

The apportioning of the costs of alternates accruing as a benefit from the major reservoir site on the Monocacy is as follows:

		Present	1985	2010
Municipal Water Supply	($/yr)	-	-	172,000
Quality Control	($/yr)	91,000	419,000	1,056,000

Figure 124 shows the benefits as they would accrue to the major reservoir considered to serve the area.

Potomac River
Dickerson, Maryland

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Cooling	(cfs)	[525]	[1050]	[1575]
Quality Control	(cfs)	400	603	785

There are no water supply requirements, and quality control flows are met by the low flows in the stream. Since the cooling water needs exceed the stream flows there would be an incidental cooling benefit obtained from any increased flows.

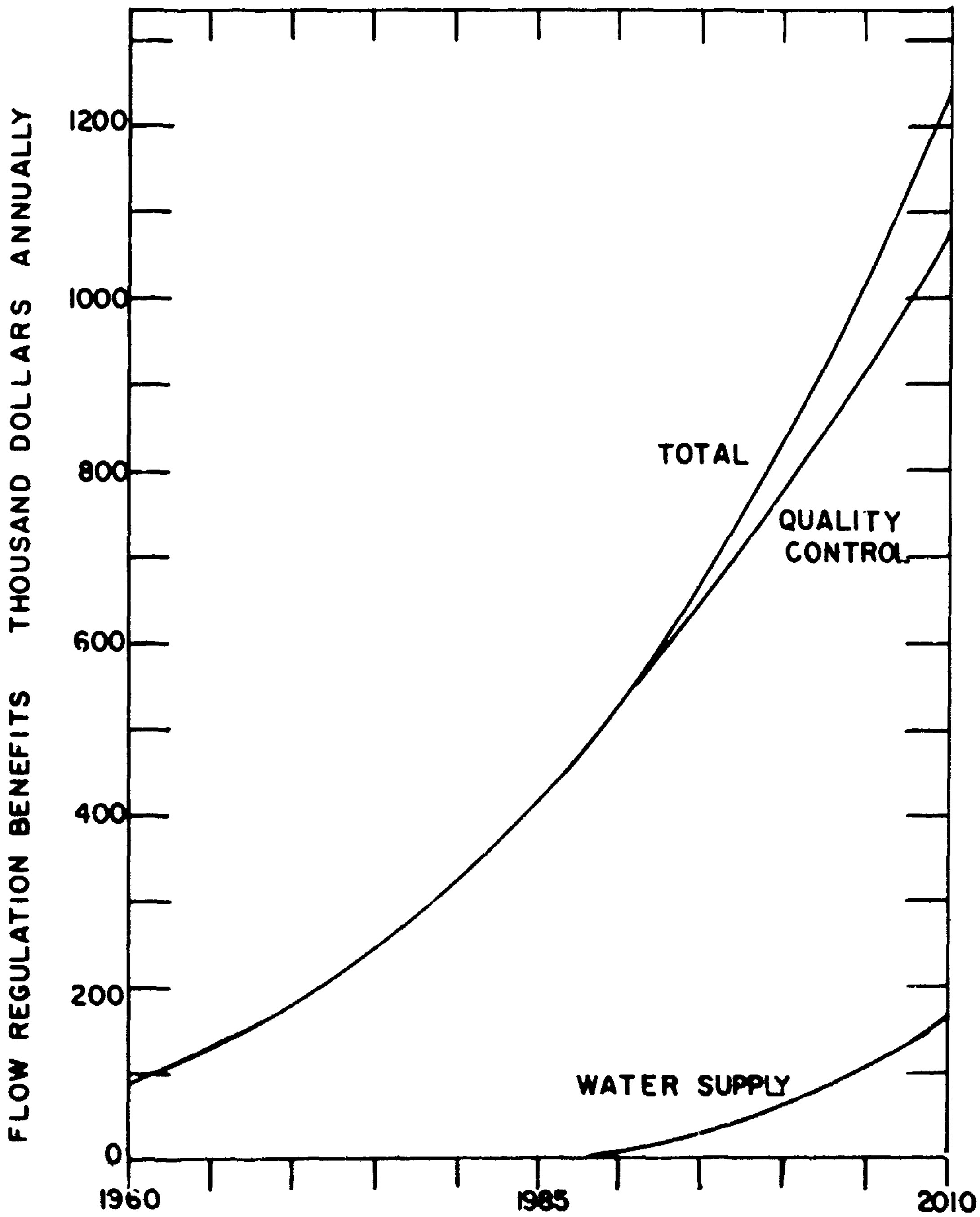
		Present	1985	2010
Cooling Requirement	(cfs)	525	1050	1575
Design Flow	(cfs)	708	708	708
Additional Cooling Requirements	(cfs)	none	342	867
Make-up Water Requirements	(cfs)	none	9	22
Equivalent Annual Cost	($/yr)	-	527,000	1,339,000

Figure 125 shows the annual benefit that would accrue to upstream reservoirs if this flow is provided.

Potomac River
Great Falls and Downstream

Present and Projected Future Requirements (Part VII):

		Present	1985	2010
Municipal Water	Max. (cfs)	562	1126	1911
	Avg. (cfs)	442	899	1589
Quality Control	(cfs)	2950	3650	3750



MONOCACY RIVER
FREDERICK, MD.

FIGURE 124

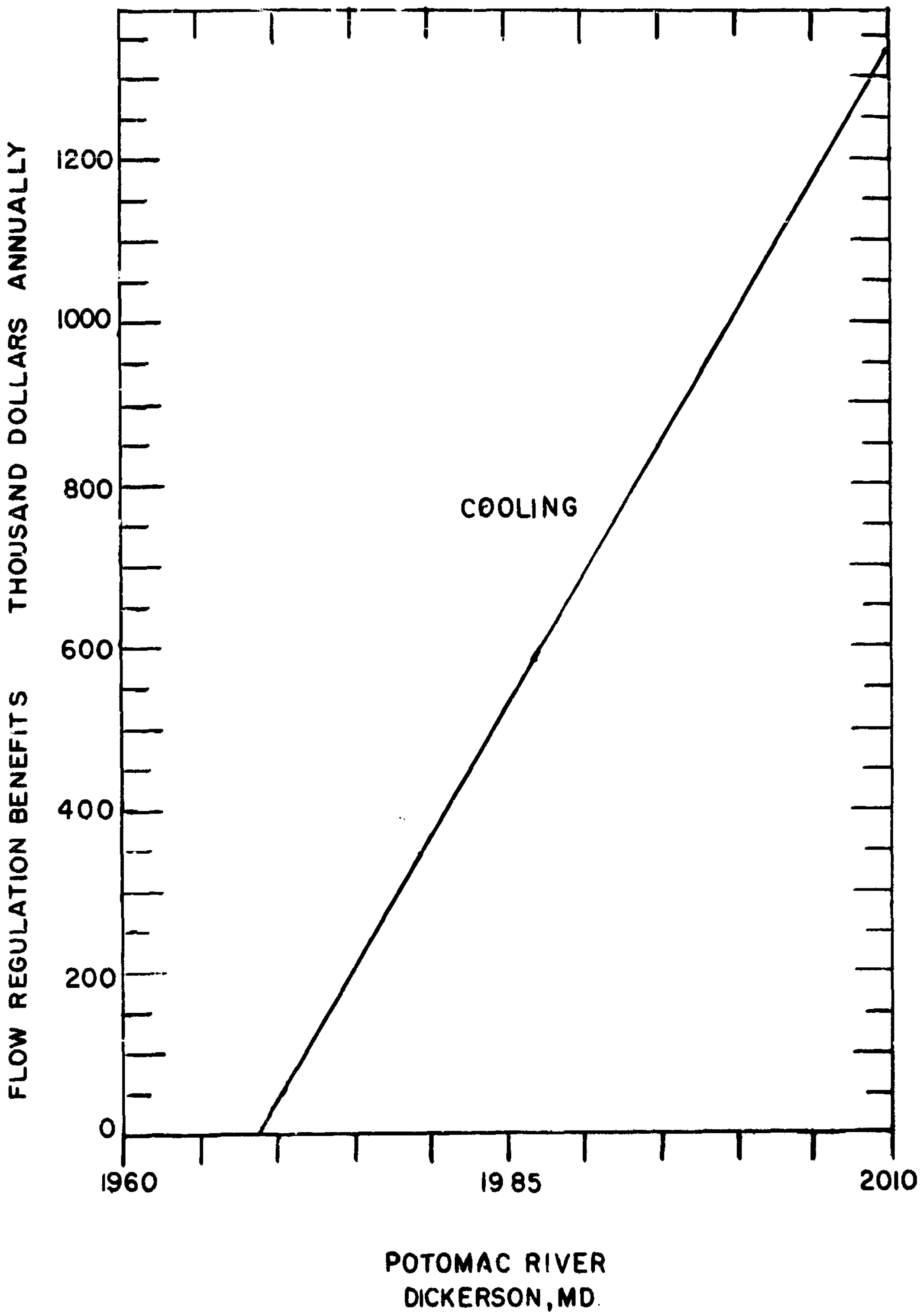

FLOW REGULATION BENEFITS THOUSAND DOLLARS ANNUALLY
1200
1000
800
600
400
200
0
COOLING
1960
1985
2010
POTOMAC RIVER
DICKERSON, MD.

FIGURE 125

Alternate Cost - Total Needs

	Present	1985	2010
Total Average Requirements (cfs)	3392	4549	5339
Design Flow (cfs)	1100	940	820
Supplemental Flow Required (cfs)	2292	3609	4519
Annual Cost of Alternates ($/yr)	6,303,000	11,188,000	14,913,000
Apportionment of Cost			
Water Supply ($/yr)	-	263,000	2,960,000
Quality Control ($/yr)	6,303,000	10,925,000	11,953,000

Figure 126 shows the benefits that would accrue for water supply and quality control in the area. All upstream reservoirs would contribute to the flows in this area.

Table 97 identifies the areas that have a future need for water supply and/or quality control flow regulation but cannot be served directly by major reservoirs. In each case a diversion is necessary either to meet the needs or transport the waste to a larger stream flow for assimilation.

Table 97

Need Areas That Cannot Be Served By Major Reservoirs But Can Be Served By Other Means

Location	Type Requirement	Means of Service
Antietam Creek Waynesboro, Pa.	Water Supply Quality Control	Local Impoundments. Pipeline to Potomac.
Antietam Creek Hagerstown, Md.	Water Supply Quality Control	Potomac at Williamsport. Pipeline to Potomac. Local Impoundments.
South River Shenandoah Waynesboro, Va.	Water Supply Quality Control	Local Impoundments. Possible Diversion from Reservoir to South River. Piping Treated Wastes to Confluence with South Fork.
Opequon Creek Martinsburg, W. Va.	Water Supply Quality Control	Local Impoundments for Water Supply. Pipe Treated Wastes to Potomac.

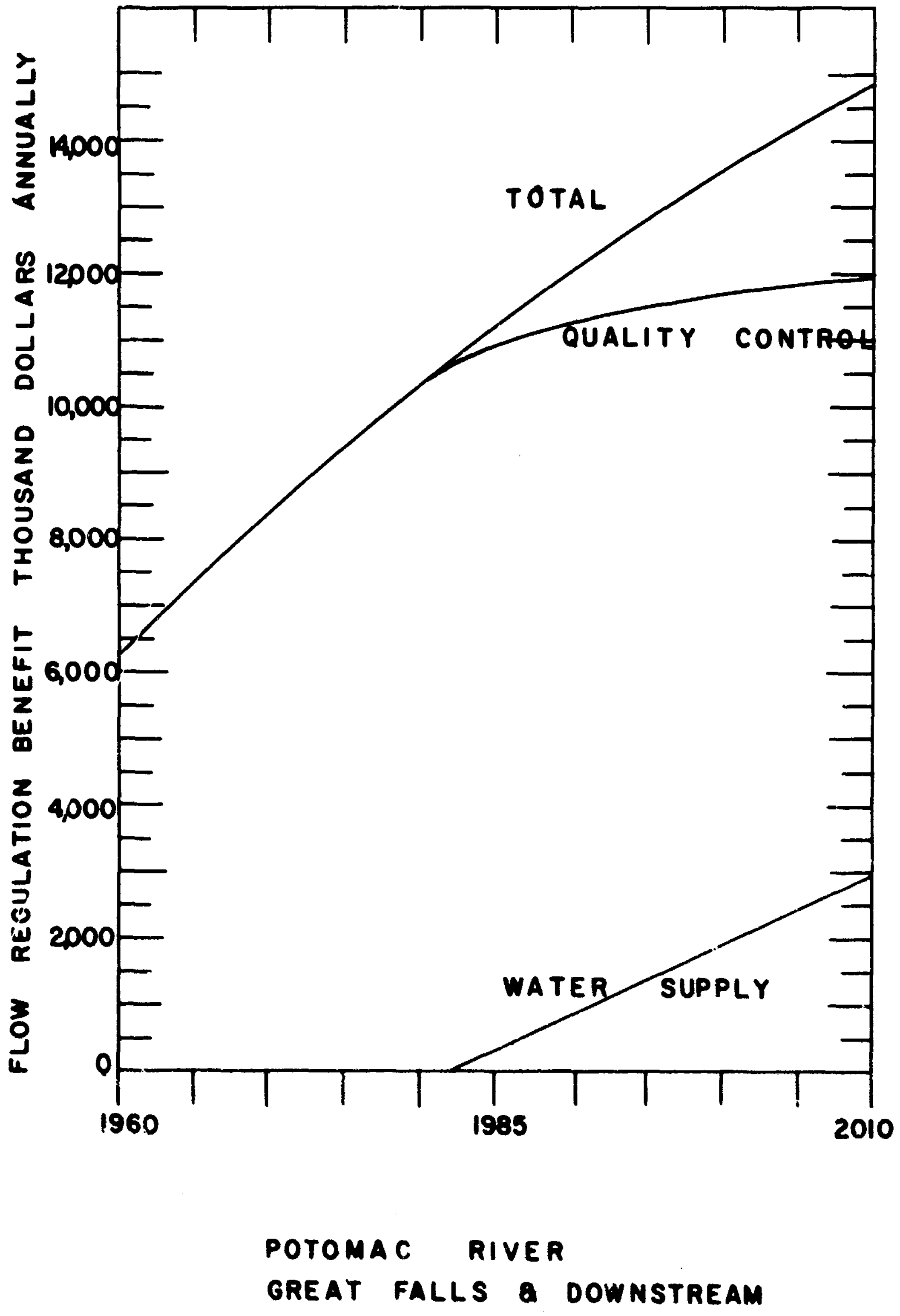

FLOW REGULATION BENEFIT THOUSAND DOLLARS ANNUALLY
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1960
1985
2010
TOTAL
QUALITY CONTROL
WATER SUPPLY
POTOMAC RIVER
GREAT FALLS & DOWNSTREAM

FIGURE 126

Antietam Creek
Waynesboro, Pennsylvania

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Municipal Water Supply	Max. (cfs)	5.1	12.3	25.8
	Avg. (cfs)	3.4	9.1	20.2
Quality Control	(cfs)	18.0	28.5	37.0

Waynesboro presently uses water from Little Antietam Creek and Rattlesnake Creek as a source of water supply. They have raw water storage of 1.5 million gallons. For this area to receive a benefit from major reservoirs a pipeline would be required. This would probably be from the site on Main Stem Conococheague at Chambersburg and would be more costly than developing the headwater sites above Waynesboro for water supply and quality control.

If water supply needs are met with the development of headwater sites above Waynesboro the total needs would be reduced to those of quality control. There are sites below Waynesboro and above Hagerstown that although not ideally situated could do much to relieve the quality control problem. The alternate considered is a pipeline to carry the wastes from Waynesboro to the Potomac River where there is adequate dilution. These wastes would essentially amount to the water supply volume of 5.1 cfs for the present, and 25.8 cfs for 2010. A pipeline would be developed for the 2010 figure and would cost approximately $8 million.

No benefit from any major reservoirs would accrue for this area.

Antietam Creek
Hagerstown, Maryland

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Municipal Water Supply	(cfs)	Potomac	Potomac	Potomac
Industrial Water Supply	(cfs)	.9	1.9	2.8
Quality Control	(cfs)	67.0	108.0	148.0
Cooling	(cfs)	[49.5]	[92.0]	[138.0]

Hagerstown is presently getting its municipal water supply from the Potomac River at Williamsport. Expansion of present facilities would supply future requirements.

Natural stream flow is sufficient to supply industrial needs.

Quality control flow needs cannot be obtained from major reservoirs so no benefit would accrue for flow regulation from them. Return flows from Waynesboro and development of headwater sites in the basin would improve the water quality.

An alternate of piping the wastes to the Potomac for assimilation would cost approximately $7 million.

South River Shenandoah
Waynesboro, Virginia

Present and Projected Future Requirements (Part V):

			Present	1985	2010
Municipal Water Supply	Max.	(cfs)	3.9	8.9	18.2
Industrial Water Supply		(cfs)	6.0	13.6	21.0
Quality Control		(cfs)	139.0	192.0	231.0
Cooling		(cfs)	[17.2]	[38.7]	[60.2]

Municipal Water Supply

The present supply has a firm yield of 14 cfs and should be sufficient until about the year 2000. The increase in supply can come from headwater sites available in the area.

Industrial Process Water

There are sufficient wells existing with yields enough to provide for future requirements.

Cooling Requirements

Part of the cooling water needs are now being met with ground water and some are taken from South River. The minimum design flow of 21 cfs in South River would meet the needs until about 1985 and then headwater sites may be developed to increase the flow or cooling towers used for supplemental cooling.

Quality Control

		Present	1985	2010
Requirements	(cfs)	139.0	192.0	231.0
7-Day, 10-Year Design Flow	(cfs)	26.0	26.0	26.0
Wells and Springs for Water Supply and Cooling Return	(cfs)	35.0	35.0	35.0
Headwater Site Development	Max.(cfs)	55.0	55.0	55.0
Total Design Flow	(cfs)	116.0	116.0	116.0

It would be possible to divert 115 cfs from the Middle River site to meet the remaining quality control requirements. However, the annual cost per cfs for such diversion would be high. Instead of diverting the 115 cfs from Middle River to South River, a more economic alternate would be to pipe the wastes from Waynesboro to the confluence of South River and South Fork where the flows from the Middle River site can supplement the quality control flows.

If Waynesboro wastes are piped to the South Fork, there will be an increase in the quality control flows needed at Elkton and downstream on the South Fork.

The flows needed for quality control were recalculated, assuming Waynesboro treated effluent as being discharged to the South Fork. Resultant quality control flows needed in downstream areas are tabulated below if this alternate is adopted.

The benefit from flow regulation for Waynesboro will be the alternate cost to alleviate the conditions at Elkton.

The "flow required (1)" is the quality control flow required in the stream reach noted if Waynesboro treated effluent is discharged directly to South River, and the "flow required (2)" is the quality control flow required for the stream reach noted if Waynesboro effluent is discharged to the South Fork.

South Fork Shenandoah
Elkton, Virginia

		Present	1985	2010
Flow Required (2)	(cfs)	292	396	480
Flow Required (1)	(cfs)	256	348	425
Added Flow Required	(cfs)	36	48	55
Annual Cost of Alternates	($/yr)	263,000	365,000	446,000

These costs include the cost of the sewer to carry the wastes to the South Fork plus the cost of providing the required flows at this point.

South Fork Shenandoah
Below Mouth of Hawksbill Creek

		Present	1985	2010
Flow Required (2)	(cfs)	280	380	457
Flow Required (1)	(cfs)	251	342	415
Added Flow Required	(cfs)	29	38	42

Shenandoah River
Front Royal and Riverton, Va.

		Present	1985	2010
Flow Required (2)	(cfs)	248	346	421
Flow Required (1)	(cfs)	243	336	412
Added Flow Required	(cfs)	*	10	9

Shenandoah River
Millville-Charles Town, West Virginia

		Present	1985	2010
Flow Required (2)	(cfs)	242	338	411
Flow Required (1)	(cfs)	238	329	404
Added Flow Required	(cfs)	*	*	7

Opequon Creek
Martinsburg, West Virginia

Present and Projected Future Requirements (Part VI):

			Present	1985	2010
Municipal Water Supply	Max.	(cfs)	6.5	12.5	25.0
	Avg.	(cfs)	4.3	9.6	19.1
Industrial Water Supply		(cfs)	5.1	9.3	13.4
Quality Control		(cfs)	67.0	90.0	113.0
Cooling		(cfs)	[2.3]	[5.1]	[7.7]

Abandoned quarries and springs are presently being used as water supply for this area. Future needs could be met with local surface impoundments or piping water from the Potomac River. Local surface impoundments would be more economical.

Cooling water needs are presently being met by ground water, and sources are sufficient for the projected future. About half of the flow required for future quality control at Martinsburg can be developed in Opequon Creek and eventually the secondary effluent could be piped to the Potomac to maintain objectives.

The return flows from Winchester water supply and supplemental quality control flows have sufficient time for recovery and will improve the quality at Martinsburg for the present.

The flows in the Potomac are sufficient to assimilate the secondary effluent.

* Present stream flows are sufficient to meet added needs.

Table 98 lists the areas that cannot be served by major reservoirs and the alternate means by which the requirements can be met.

Table 98

Need Areas That Cannot Be Served By Major Reservoirs

Location	Type Requirement	Possible Means of Providing
Moorefield River Moorefield, W. Va.	Quality Control	Local Surface Impoundments
Warm Springs Run Berkeley Springs, W. Va.	Water Supply Quality Control	Ground Water Pipeline to Potomac
Back Creek Dehaven, W. Va.	Water Supply Quality Control	Groundwater and Winchester Local Impoundments
North River Shenandoah Harrisonburg, Bridgewater, Dayton, Va.	Water Supply Quality Control	Headwater Impoundments
Catoctin Creek Purcellville, Hamilton, Va.	Water Supply Quality Control	Ground Water; Pipeline to or from Potomac River, Local Surface Impoundments
Goose Creek Leesburg, Va.	Water Supply Quality Control	Springs and Wells Local Impoundments

The following section discusses each area briefly, its needs, and possible method of meeting the needs.

Moorefield River
Moorefield, West Virginia

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Municipal	Max. (cfs)	0.6	2.0	4.3
Industrial	(cfs)	0.5	1.0	1.4
Quality Control	(cfs)	16.6	25.3	33.0

Since the minimum natural flow in the stream is sufficient for water supply needs, any benefits which accrue would be for quality control. However, due to its location, no major reservoirs can serve this area. There are several headwater sites above Moorefield that could supply the needed water.

Generally, the waters of the Moorefield River above Moorefield are of good quality, while quality below Moorefield does not meet the specifications for Class "C" waters. See Part III, page for discussion of water quality in this area.

This condition exists between Moorefield, West Virginia, and the confluence of Moorefield River and South Branch. There is enough existing flow in South Branch to alleviate this condition below the confluence.

Warm Springs Run
Berkeley Springs, West Virginia

Berkeley Springs is in an area that cannot be served by any major project considered; therefore, no benefit will accrue to major reservoirs in this area.

Domestic water supplies are now obtained from ground water with relatively little treatment. Industrial process water is obtained from ground water and surface water, depending on quality needed.

Alternates for water supply are expansion of present ground water sources, local surface impoundment, or pumping of water from the Potomac River.

The principal wastes in this area are from domestic use, cannery, silt and clay from glass-sand operation. Part III of the report discusses this area and its wastes. It is possible for treated wastes from the area to be piped to the Potomac where sufficient flow exists to assimilate them.

Back Creek
Dehaven, West Virginia

Present and Projected Future Requirements (Part VI):

		Present	1985	2010
Municipal Water Supply	(cfs)	Ground	Winchester	Winchester
Quality Control	(cfs)	7.5	11.5	16.5

The present water supply needs of this area are met with existing ground water. It is expected that present sources will be used to capacity and future water supply will come from Winchester, Virginia. The total annual benefit to this area would be for quality

control. Major wastes are domestic, and silt and clay from sand and gravel washing. The annual benefits for quality control would not accrue to any major reservoir due to location, but there are headwater sites in the upstream area that could be utilized for this purpose.

North River Shenandoah
Harrisonburg, Bridgewater, Dayton, Virginia

Present and Projected Future Requirements (Part V):

		Present	1985	2010
Municipal Water Supply	(cfs)	5.4	14.5	33.7
Quality Control	(cfs)	23.0	52.0	77.0

Part V, page 319 discusses water use of the area and waste treatment is covered on pages 327 and 328.

Harrisonburg presently obtains water from an underground gallery on Dry Creek, 15 miles west of the city. Demand during the three dry months of the year exceeds the firm yield of 2 MGD, at which times the supply is supplemented by water from Silver Lake. This source can supply an additional 2 MGD and requires treatment for hardness reduction.

The source of water for municipal use at Bridgewater is Warm Springs located one mile south of the town. The firm yield is .35 MGD and requires treatment for hardness reduction. Future plans are to take water supply from North River.

Dayton presently gets water for municipal use from a small spring with a yield of about 150,000 gpd.

The low flows in North River are of sufficient quantity for water supply until about 1990, but will be deficient for quality control in a few years. Headwater sites developable in this area would provide sufficient low flow for water supply and quality control.

Catoctin Creek - Purcellville, Hamilton, Virginia
Goose Creek - Leesburg, Virginia

Although there is a need for water supply and quality control flows in these areas, no benefit would accrue to any of the major reservoirs from storage. These areas are now supplied by ground water. When the supplies are exhausted it is proposed to pipe water supply from the Potomac River and return wastes by pipeline to the Potomac. The natural flows in the Potomac are sufficient to meet these needs; therefore, no benefits would accrue to any major reservoir sites considered.